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RECORD OF THE PROGRESS

OF

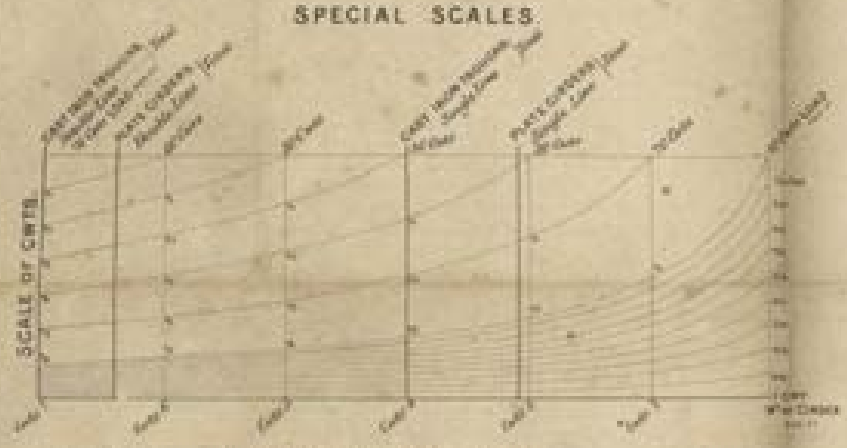
MODERN ENGINEERING.

DIAGRAMS GIVING WEIGHTS OF C

Horizontal Scale 10 Ft. Span - 1 Inch. Ve

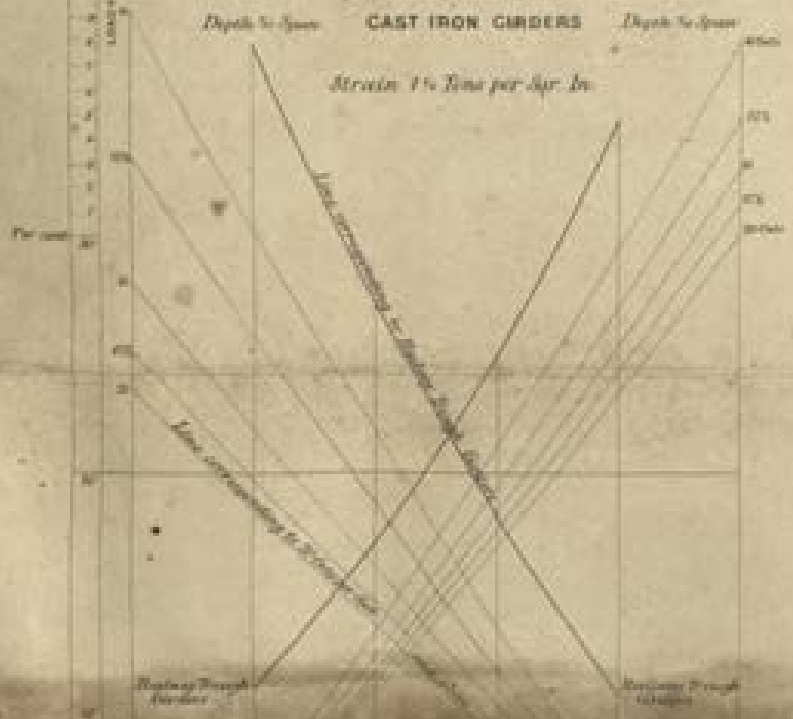
The Vertical Height from Span on Base Line to Curved Line corresponding to Load per foot (exclu
Load per foot that a Plate Girder (Depth $\frac{1}{9}$ Span, Strain 4½ Tons per inch) will weigh per foot.
Or, by using Special Scale corresponding to the Load per foot, the Vertical Height gives the Weight

SPECIAL SCALES



Depths to Spans — CAST IRON GIRDERS — Depths to Spans

Strain 1½ Tons per Sqr. In.



SPECIAL CASES

STRAIN.—As the proposed Strain is to 4½ Tons per square inch, so is the Load per foot to the equivalent Load on Diagram

DEPTH.—Within the limits of $\frac{1}{8}$ to $\frac{1}{12}$ Span. For every unit in Denominator above or below $\frac{1}{10}$, add or subtract the Percentage corresponding to Load per foot, and Span on Diagram No. 2 below Base Line

BOX GIRDERS.—The Percentage may be taken as the mean between that due to the Load per foot, and that due to half the Load per foot. (If the Load per foot including Girder exceed [illegible] in Cwts. the Girder should be Box)

LATTICE GIRDERS.—The Percentage may be taken as the mean between that due to the Load per foot, and that due to 56 Cwts. less the approximate Weight of Girder (to be taken from Diagram). (If Load per foot including Girder is less than [illegible] in Cwts., the Lattice is lighter than Plate

RAILWAY BRIDGES.

Special Scales are shown by using which the Vertical Height on Diagram to Line corresponding to Railway Girders is the total Weight of Iron per foot in Cwts. for entire Bridge.

For Floors of Bridges the following Weights may be taken:—

Single Line.	Double Line.
(Span − 4) × 2.2 or 2.4 Cwts	(Span − 4) × 4.4 or 4.8 Cwts
(Span + 3) × 1.4 or 1.6 "	(Span + 3) × 2.8 or 3 "

The total Weight of Iron in Bridge 90 feet Span.

Double Line, including Floor Plates.

	Span	Length	Weight per ft.	Total Cwts.
Main Girders	90	97	× 12.4 =	1203
Cross "	90 − 4 =	86	× 6.6 =	567
Plating	90 + 3 =	93	× 2.6 =	242

Total Weight 1,914 Cwts.

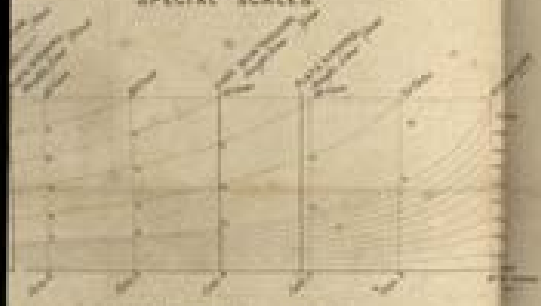
DIAGRAMS GIVING WEIGHTS OF GIRDERS UP TO 200 FEET SPAN.

Horizontal Scale 10 Ft. Span 1 Inch Vertical Scale 5 per cent 1 Inch

The Vertical Height from Span in Base Line to Curved Line corresponding to Load per foot (inclusive of Girder) in the Percentage of Load per foot that a Plate Girder (Depth ⅛ Span, Stress 6½ Tons per Inch) will weigh per foot. Or, by using Special Scale corresponding to the Load per foot, the Vertical Height gives the Weight of Girder per foot in Cwts.

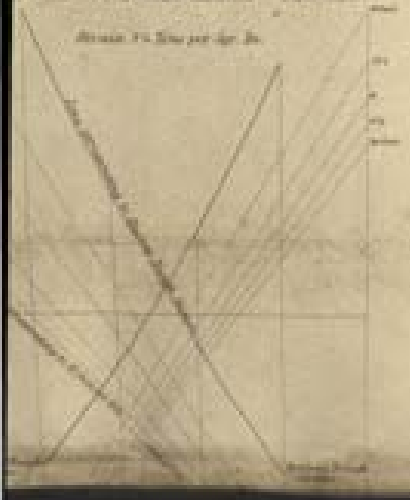
Thus 30 ft. 10 ft. 13.7 = 4.38 = 87 = 200 Cwts.
Thus Do. Do. = 4.38 = 87 = 200 Cwts.

SPECIAL SCALES.



CAST IRON GIRDERS. Depth ⅛ Span

Stresses 5½ Tons per Sqr. In.



SPECIAL CASES.

STRAIN.—As the proposed Stress is to 6½ Tons per square inch, so is the Load per foot to the equivalent Load on Diagram.

Thus 6½ : 5 Tons :: 10 : 7.7

= 10 = 11.1 = 4 Cwts per foot

TAPER.—With a Taper of ¼ to ⅛ Span, for every inch in Thickness greater or below ½, add or subtract the Percentage corresponding to Load per foot and Span on Diagram No. 1 below Base Line

10 10 13.7

= ½ less 18.10 = 4 = 4

= 1.8 =

60 = 13.5 = 4.05 Cwts

BOX GIRDERS.—The Percentage may be taken as the mean between that due to the Load per foot, and that due to half the Load per foot. If the Load per foot including Girder cannot [illegible] in Cwts. the Girder should be free

60 10 13.7 + 14.5 = 2

60 = 14.1 = 4.23 Cwts

LATTICE GIRDERS.—The Percentage may be taken either as that due to the Load per foot, and that due to ½ Cwts. less (being the [illegible] Weight of Girder [illegible] be taken from Diagram) the Load per foot including Girder is less than [illegible] in Cwts., the Lattice is lighter than Plate

60 10 13.7 + 14.5 = 2

60 = 13.1 = 4.10 Cwts

RAILWAY BRIDGES.

Special Scales are shown by using which the Vertical Height corresponding to Line corresponding to Railway Girders is the total Weight of Iron per foot in Cwts. for certain Bridges.

For Floor of Bridge the following Weights may be taken viz:—

Single Line.	Double Line.
25 ft. Span = 6.5 = 1.1 Cwts.	25 ft. Span = 6.5 = 1.1 Cwts.
200 ft. Span = 6.5 = 1.1 = 3.6 =	200 ft. Span = 6.5 = 1.1 = 3.6 = 9

The Total Weight of Iron in Bridge 90 feet Span.

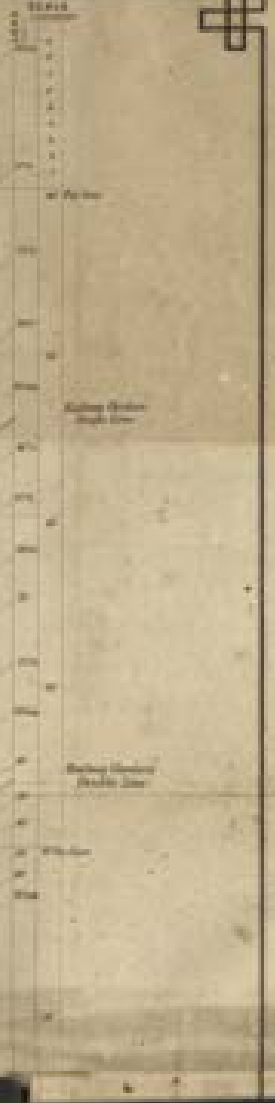
Single Line, inclusive Floor Plates—

Main Girders	90	17	12.1	1170
Cross	10 × 4	40	8.1	647
Plating	90 × 3	30	8.1	243

Total Weight 1,814 Cwts.

NOTE.

The Diagrams give Weights of Girders of the average construction and the most economical possible.



Plate

RAILWAY BRIDGES.

Scales are shown by using which the Vertical ... to Line corresponding to Railway Girders ... Weight of Iron per foot in Cwts. for entire Bridge. ... Bridges the following Weights may be taken —

Single Line.	Double Line.
(Spans – 4) × 2.2 or 2.3 Cwts	(Spans – 4) × 4.6 or 4.7 Cwts
(Spans + 3) × 1.8 or 1.9 "	(Spans + 3) × 3.8 or 4 "

... Weights of Iron in Bridge 90 feet Span.

SINGLE LINE, INCLUDING FLOOR PLATES.

Span	Length	Wt. per ft.	Total Cwts.
90	92	× 11.4 =	1155
90 – 4 =	88	× 4.6 =	367
90 + 3 =	93	× 2.6 =	242
		Total Weight	1,914 Cwts.

Line corresponding to Weight per foot of Single Line of Girders, if weight of Girders

Line corresponding to Weight per foot of Double Line of Girders, Single Line

Line corresponding to 20 Cwts per foot Load each shore

Theoretical curvature for any Load per foot more

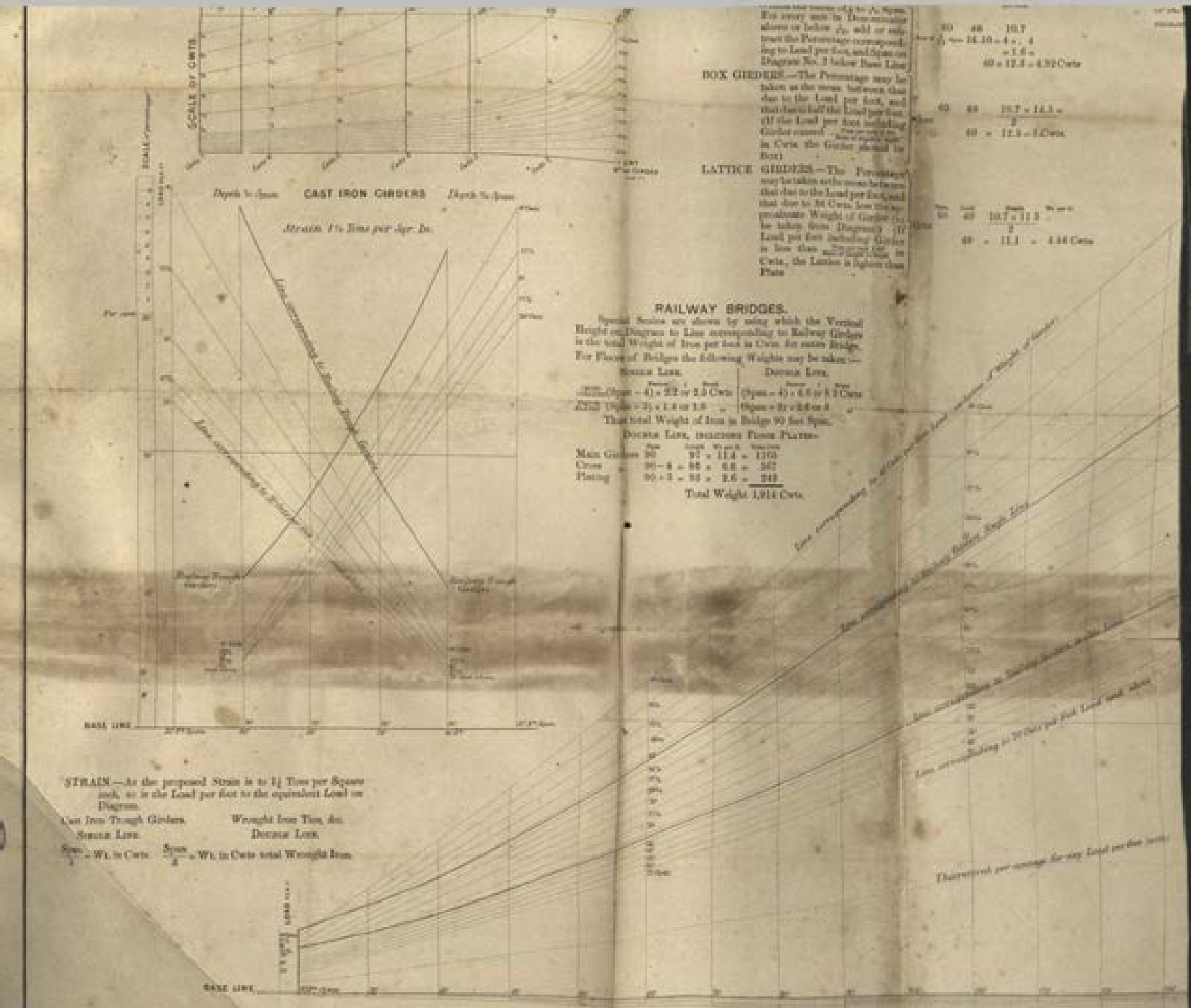
Railway Girders Double Line

B. BAKER

WATER Level. BASE LINE

N° 2

... with Main Girders 80 ft. Span, and Cross Girders 6 ft. apart, resting on Top of Main Girders. Load 1 Cwt. per ... 24 Cwts. per foot); and load on Main Girders = Span of Cross Girders × 4 Cwts. By trying different spans of ... Span of Cross Girder = 16 ft., and that therefore would be the proper distance apart of Main Girders.


SCALE OF CWTS.
Depth ⅛ Span
CAST IRON GIRDERS
Depth ⅛ Span
Strain 1½ Tons per Sqr. In.
Line corresponding to Rolling Load Girders
Line corresponding to Trough Girders
Railway Trough Girders
Box Lattice Trough Girders
BASE LINE
Line corresponding to Railway Bridge Girders Single Line
Line corresponding to Railway Bridge Girders Double Line
Line corresponding to 20 Cwts per Foot Load each where
Theoretical percentage for any Length not there given
BASE LINE

BOX GIRDERS.—The Percentage may be taken as the mean between that due to the Load per foot, and that due to half the Load per foot, (If the Load per foot including Girder exceed ... in Cwts. the Girder should be Box)

LATTICE GIRDERS.—The Percentage may be taken as the mean between that due to the Load per foot, and that due to 56 Cwts. less the approximate Weight of Girder (to be taken from Diagram) (If Load per foot including Girder is less than ... in Cwts., the Lattice is lighter than Plate

60 48 10.7
$\frac{10.7 + 11.3}{2}$ = 11.0 - 4 = 4
= 1.6 =
40 = 12.4 = 4.32 Cwts

60 40 $\frac{10.7 + 14.3}{2}$ =
40 = 12.5 = 5 Cwts.

60 40 $\frac{10.7 + 11.5}{2}$ =
40 = 11.1 = 4.44 Cwts

RAILWAY BRIDGES.

Special Scales are shown by using which the Vertical Height on Diagram to Line corresponding to Railway Girders is the total Weight of Iron per foot in Cwts. for entire Bridge.

For Floors of Bridges the following Weights may be taken:—

Single Line.	Double Line.
⅓ (Span − 4) + 2.2 or 2.5 Cwts.	(Span − 4) + 1.6 or 1.7 Cwts
⅓ (Span + 3) + 1.4 or 1.6 "	(Span + 8) + 1.6 or 1.8 "

That total Weight of Iron in Bridge 90 feet Span.

Double Line, including Floor Plates.

	Span	Length	Weight	Tonnage
Main Girders	90	97	× 11.4 =	1105
Cross "	90 + 8	98	× 4.8 =	567
Plating	90 + 3	93	× 2.5 =	233
			Total Weight	1,914 Cwts.

STRAIN.—As the proposed Strain is to 1½ Tons per Square inch, so is the Load per foot to the equivalent Load on Diagram.

Cast Iron Trough Girders. Single Line. $\frac{\text{Span}}{3}$ = Wt. in Cwts.

Wrought Iron Ties, &c. Double Line. $\frac{\text{Span}}{2}$ = Wt. in Cwts total Wrought Iron.

Various uses of the Diagram suggest themselves; for instance, Given a space to cover, say 80 ft. × 80 ft. with Main Girders 80 ft. Span, and Cross Girders 4 ft. apart, resting on Top of Main Girders, Load 4 Cwts. per Square foot. Required the most economical distance apart of Main Girders. Now load on Cross Girders = 24 Cwts. per foot; and load on Main Girders = Span of Cross Girders × 4 Cwts. By using different spans of Cross Girders, the sum of percentages of Cross Girders and Main Girder will be found the minimum when Span of Cross Girder = 16 ft., and this therefore would be the proper distance apart of Main Girders.

E. & F. N. SPON, 48, HAYMARKET, LONDON.

W. Hamilton Mee

Jean Hawksley

PHOTOGRAPHED BY CUNDALL DOWNES & Co

London: E. & F. N. Spon, 16 Bucklersbury

RECORD OF THE PROGRESS

MODERN ENGINEERING

COMPRISING

CIVIL, MECHANICAL, MARINE, HYDRAULIC, RAILWAY, BRIDGE,
AND OTHER ENGINEERING WORKS.

WITH

ESSAYS AND REVIEWS.

63623

EDITED BY

WILLIAM HUMBER,

ASSOCIATE OF INSTITUTE OF CIVIL ENGINEERS, AND MEMBER OF INSTITUTE OF MECH. ENGINEERS.

SECOND EDITION.

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1864.

LONDON:
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32, CLEMENT'S LANE, E.C.

ILLUSTRATIONS.

Name and Description.	Situation.	Plates.	Name of Engineer.
Victoria Station and Roof—London, Brighton, and South Coast Railway	Pimlico	1 to 8	Mr. R. Jacomb Hood, C.E.
Southport Pier	Southport	9 and 10	Mr. James Brunless, C.E.
Victoria Station and Roof—London, Chatham, and Dover, and Great Western Railways	Pimlico	11 to 15A	Mr. John Fowler, C.E.
Roof of Cremorne Music Hall	Chelsea	16	Mr. William Humber, C.E.
Bridge over Great Northern Railway	Knebworth	17	Mr. Joseph Cubitt, C.E.
Roof of Station—Dutch Rhenish Railway	Amsterdam	18 and 19	Mr. Euschedi, C.E.
Bridge over the Thames—West London Extension Railway	Battersea	20 to 24	Mr. William Baker, C.E.
Armour Plates	...	25	Mr. James Chalmers, C.E.
Suspension Bridge over the Thames	Lambeth	26 to 29	Mr. Peter W. Barlow, C.E.
The Allen Engine	..	30	Mr. G. T. Porter, M.E.
Suspension Bridge over the Avon	Clifton	31 to 33	Mr. John Hawkshaw, C.E., and W. H. Barlow, C.E.
Underground Railway	London	34 to 36	Mr. John Fowler, C.E.

NOTE TO THE BINDER.

The Plates to be bound at the end of the Volume. Biographical Sketch of the Life of J. HAWKSHAW, Esq., *to precede Address.*

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BIOGRAPHICAL SKETCH OF J. HAWKSHAW, Esq., F.R.S., F.G.S.

JOHN HAWKSHAW, Esq., F.R.S., F.G.S., and President of the Institution of Civil Engineers, and of whom we give a photograph likeness forming a frontispiece to our volume for 1863, was born at Leeds in 1811, and was educated at the Leeds Grammar School.

When the establishment of Railways was in its infancy, Mr. Hawkshaw had already determined upon his future career, and was a pupil under Mr. Charles Fowler. He afterwards became an assistant to that celebrated engineer Mr. Alexander Nimmo, who was largely employed by Government on public works in Ireland.

On Mr. Nimmo's death, in 1831, Mr. Hawkshaw went to South America to take charge of the Bolivar Copper Mines. On his return to England he became connected with the late well-known Engineer Mr. James Walker, and after acting as his assistant for about three years was in 1837 appointed Engineer to the Manchester and Bolton Canal and Railway. Mr. Hawkshaw soon afterwards became Engineer to the Manchester and Leeds Railway, which formed the nucleus of the Lancashire and Yorkshire system, nearly the whole of which Railways he constructed, embracing several works of very large magnitude. The difficult nature of the district through which some of these Railways pass rendered it necessary to adopt steeper gradients than had hitherto been attempted to be worked by the Locomotive Engine. Mr. Hawkshaw clearly proved, in the face of much opposition, the practicability of introducing such a change, and its desirability even when, by taking more circuitous routes, easier inclines could be secured. The soundness of the views he so successfully advocated are now generally admitted, and their recognition has conduced to a not inconsiderable extent to the rapid extension of the Railway system not only throughout the country, but also throughout the whole of the civilized world.

In addition to the Lancashire and Yorkshire Railway, Mr. Hawkshaw has constructed several other Lines, the most important Railway work on which he is now engaged being, perhaps, from the magnitude of the operations, the Charing Cross Railway, involving, although the line is only three miles long, two large bridges over the Thames, besides some very extensive street bridges and two terminal stations, the Charing Cross and the Cannon Street. Mr. Hawkshaw still continues to be the Consulting Engineer of the Lancashire and Yorkshire Railway Company, and is also the Consulting Engineer to the South Eastern Railway Company.

Mr. Hawkshaw is Engineer to the Penarth Harbour Dock and Railway, and to the Hull Docks, where he is constructing extensive works.

The Londonderry Bridge in Ireland has just been completed by him, and the Hull South Bridge is being carried out under his directions.

In Russia Mr. Hawkshaw constructed the Riga and Dünaburg Railway, and is Consulting Engineer to the Dünaburg and Witepsk Railway, the works of the latter being now in active operation.

In India Mr. Hawkshaw is Consulting Engineer to the Madras Railway, and to the Eastern Bengal Railway. He is also Consulting Engineer to the Railways now being constructed in the Mauritius by the Government of that Colony.

On the death of the late Mr. Rendel, Mr. Hawkshaw succeeded him as Engineer-in-Chief to the Government Harbour of Refuge, and other works, at Holyhead. Mr. Hawkshaw also commenced, and is carrying out for the War Office the foundations of the new Forts to be built in the sea at Spithead. He is extensively consulted, and is frequently called upon to report, both by the British and other Governments, on matters of a professional character. He was one of the Metropolitan Commissioners of Sewers when that body was appointed by the Crown, and has been Arbitrator between contending companies and parties, and has had to report on a great number and variety of important and difficult engineering cases.

In 1860 Mr. Hawkshaw was appointed sole Royal Commissioner to decide between numerous contending schemes for the water supply of the City of Dublin, and the one he recommended after a lengthened investigation, is now being carried out.

In May, 1862, when the failure of the Middle Level Sluice at St. Germans, near Lynn, occurred, whereby a large area of country was flooded, and the safety of the district endangered, Mr. Hawkshaw was called in by the Commissioners, and succeeded in adopting speedy remedial measures, which have proved successful; and, instead of constructing a new sluice, invented and erected the syphons for the drainage of the district, which continue to act in a satisfactory manner.

Towards the end of 1862, Mr. Hawkshaw, at the request of His Highness the late Viceroy of Egypt, Said Pacha, visited that country with the view of reporting on the feasibility of the Suez Ship Canal for connecting the Mediterranean and Red Seas. His advocacy of the practicability of that measure as an engineering work is now well known.

As a witness before Parliamentary Committees and other tribunals, Mr. Hawkshaw is not surpassed for the clearness and honesty of his evidence, and for his unswerving maintenance of opinions, which his long and varied experience has convinced him to be correct.

Mr. Hawkshaw is still in the prime of life, and we hope he may long be spared to the profession and to the country.

MODERN ENGINEERING.

VOL. I.] JANUARY 1, 1863. [PART I.

ADDRESS.

AMIDST the numerous and varied periodical scientific publications now submitted to the public, it is apparently not easy to assign a good reason for increasing the list, perhaps already overcrowded, and with so many competitors in the field, some brilliant characteristic is indeed necessary to insure sufficient notice from the limited circle of readers to which any purely scientific or professional work is inevitably addressed; we hope, however, that we may enjoy some share of public esteem, and will endeavour to deserve it, by devoting an unremitting attention to the nature and arrangement of the matter set forth.

We do not intend to trust to quantity as an incentive to purchase our numbers, but to quality, and the work, when bound in volumes, will contain complete accounts of works executed, and not abound with mere ephemeral statements, interesting only at the period of publication, and it is, therefore, designed to be useful as a book of reference to the practical man,—supplying him with both rules and examples of the various branches of those sciences which we include in our general scheme, which we will now endeavour briefly to describe.

Particular attention will be devoted to the collection and description, both by plates showing details, and by text, of such works as have already been, or are now being, or may in future be erected, which possess sufficient interest; and it will be attempted, as a general rule, to collect such instances as may be likely to occur frequently, rather than to occupy space with accounts of those which, although interesting as exemplifying the ability of science to triumph over apparently insurmountable difficulties, may yet remain as mere monuments of the same by reason of the paucity of cases where such difficulties are encountered.

Next, with regard to the branches we propose to include in our pages, we need merely observe, that nothing connected with engineering science will be excluded, whether it be civil or mechanical, marine or hydraulic, military or telegraphic; hence we may safely rely upon never being at a loss for interesting information to communicate, and, therefore, never under the necessity of applying to those valuable assistants of so many scientific writers of the present day, "scissors and paste," and by giving information obtained from original sources, we shall hope to render inapplicable to ourselves the very common remark, that there is about as much to be learned by reading one periodical regularly as by reading half a dozen. With these intentions, we now submit our pages to the public, and all we ask or desire is fair criticism, and if we fail to come up to the standard we have set up, it will be through no lack of energy on our part.

THE PRINCIPLES OF BRIDGE AND ROOF CONSTRUCTION AS AFFECTED BY MATERIALS.

In considering the principles upon which any work is to be designed, it becomes necessary to see how far these may be affected by the nature of the material in which such design is to be executed, a fact patent to common sense, but hitherto very much neglected, thus, in the earlier iron bridges, we find a close adherence to such theories as had been applied to stone structures previously, although the contrast between the natures of the two materials, stone and iron, would seem to be sufficiently evident to fix the attention of even a superficial observer. In some of the first iron bridges it will be found that the arch is made up of cast iron voussoirs, made to approach as nearly as possible in condition as to pressure and equilibrium to those of a stone bridge, but with this difference, that the stone voussoirs were solid, whilst those of iron were hollow, in fact skeleton voussoirs; here, it is true, that, to a certain extent, advantage was taken of the superior strength of iron, but this only to a limited degree, and the result was, that although the structure was much reduced in weight, it yet remained far more cumbersome and unsightly for an iron arch, than did the former works for stone. This is quite easily accounted for on the introduction of a new material, but it is astonishing that so little progress has been made in the art of building bridges in iron, which should possess some quality not offensive to the artistic eye, and, with some engineers, even at the present day, each of their works is inferior in point of taste to its predecessor, though to others credit is due for having wandered from the beaten path, and given to the world something to show that the useful may even yet be economically accompanied by the ornamental.

If we desire to erect a stone bridge, what we have to consider in designing it, is the stability of the work, which will depend upon the equilibrium of the external forces, and this being duly attended to, we shall generally find that the quantity of material present is quite sufficient to resist any crushing strain which may be brought to bear upon it, but the question of stability *must* be looked to very closely, as we do not rely upon the annular segment under a bending strain, by reason of its want of tensile strength, for when the equilibrium of the external forces is destroyed, the voussoirs at certain parts of the arch commence revolving upon one edge on the extradosal or intradosal side, according to the position of the stone, the result of which is to produce chipping of such edges in the first instance, and ultimately inducing the failure of the entire arch.

When iron, and especially wrought iron, is the material of which the arch is constructed, the circumstances are quite different, strength being the prime question, that is to say, it is absolutely necessary that there should be a state of equilibrium existing between the external and internal forces, the forces of pressure and cohesion, and this point being attended to, the kind of strain upon the metal is not of very great importance, in fact it matters only so far as it affects the weight of material used in the construction of the work.

These remarks are also borne out by the natural taste in regard to artistic effect, and it is noteworthy, that a form which is pleasing to the eye, when the material is masonry, is not so when it is iron, although a very slight variation may render the design ornamental, though such variation will most probably slightly increase the cost of construction, so that we have to choose between loss of economy and loss of elegance of appearance, and the election will of course be influenced by the locality and other circumstances; but we shall here only refer to those cases where beauty is of importance, as, for instance, in or near large towns or buildings, and, if the latter be of peculiar design, it is generally desirable that a bridge erected in the neighbourhood be in accordance with the style of the same.

In the Metropolis we can confidently point to three good examples of arched bridges—London, Waterloo, and Westminster, the latter being perhaps the first iron arch bridge erected which has evidenced a just appreciation of the correct principles, by which a pleasing as well as useful character may be imparted to such structures.

All the foregoing remarks are also applicable to the question of roofs; but there are more examples of roofs than of iron bridges, which are of elegant form, although the common trusses are unsightly enough. In the construction of elegant roofs, however, it is sometimes necessary to use external trussing to preserve a beautiful form, without the necessity of using an excessive quantity of material, and of this method the roof of the Cremorne Music Hall (of which illustrations will be given, Plate 16) is an example.

LONDON, BRIGHTON, AND SOUTH COAST RAILWAY.

PIMLICO STATION.

DESCRIPTION OF ROOF.

Plates 1, 2, 3, 4, 5, 6, 7, and 8.

This station was erected and completed in 1861, according to the designs of Mr. Jacomb Hood, Civil Engineer, by the Horsley Company, Tipton, contractors.

The roof is 740 feet in length and 243 feet in breadth, covering in all an area of 179,820 superficial feet. The length is composed of 13 spans of 50 feet each, at the north end one span of 53 feet, and at the south end a span averaging 37 feet. These spans are supported by main girders placed transversely, forming 2 spans of 124 feet 7 inches and 117 feet 5 inches respectively. These main girders are 10 feet 9 inches deep, and rest on cast-iron columns down the centre and the east side of the roof (Plate 2)—the girders on the western side being supported by the station wall.

The columns are 30 feet in height, and 1 foot 6 inches in diameter, the shafts are fluted with ribbon bands running around them, the thickness of the metal being $1\frac{1}{2}$ inches at the thickest part; they are fixed at the bottom to a cast-iron shoe secured to the stone foundation by Lewiss bolts; the stone rests upon 9 piles braced together at the heads, and having a thickness of concrete filled in round them, the whole carrying a weight of 78 tons; the foliage on the capital is cast separately, and fastened on the column by screws. The total weight of the columns, including base and spandril brackets, is 6 tons 2 cwt.

The greatest span of the main girders is 124 feet 7 inches. The top boom or flange is formed by a wrought-iron plate and a cast-iron gutter, which is made to answer both purposes; the bottom boom is formed of flat bars 8 inches wide. The struts and ties are formed as shown in the drawing, viz., of flat and **T** iron; the rivets are all $\frac{3}{4}$-inch, the different sections are proportional to the duty they have to perform; the sectional area of the bottom bar of girders is 15 inches at centre, the tensile strain being 5·8 tons per sectional inch. The sectional area of top of girder (cast-iron) is 47 inches, having a compressive strain of 1·8 tons per sectional inch; at the junction of the struts and ties cast-iron ornaments are secured by means of bolts. The total weight of each girder is 13 tons 10 cwt. The total weight distributed on the girder, including its own weight, is 61 tons. Between the columns are fixed ornamental longitudinal girders (see Plate 6), forming a bracing. The main principals for the small spans are 12 feet $5\frac{1}{2}$ inches apart, and are formed of rafters of **T** iron, $4'' \times 4'' \times \frac{1}{2}''$, with an inclination of 2 to 1, the lower end of the rafters being secured to a snug cast upon the gutter. They each carry a distributed weight of 4·7 tons, and were tested to 9·15 tons. The struts are formed of $1\frac{1}{2}'' \times 2''$ wrought-iron piping, fitted with joints at the ends; the ties are round iron, and have a section proportional to the strain upon them. The alternate principals are **T** iron, 18 feet 10 inches long $\times 4'' \times 4'' \times \frac{3}{8}''$, fixed at their lower end similarly to the main principals, the upper end being secured by bolts to a cast-iron girder resting on the main principals.

The lower standards are cast-iron of an **H** section, placed over each main principal, and bolted to the longitudinal cast-iron girder; another standard is placed upon the centre of the main principals, upon which a cast-iron ridge piece is bolted with holes cast in it to receive the upper ends of the sash bars, the lower ends being fixed to a cast-iron girder at the top of the side standards. The sash bars are of a **T** form, 2″ high and $\frac{1}{4}$ thick on the top, and $1'' \times \frac{3}{8}''$ at bottom, the distance from centre to centre of the sash bars being 14·95 inches. Between the side standards are placed 4 louvre plates of galvanised iron $\frac{1}{8}$ inch thick, the ends being bolted to the standards by $\frac{3}{4}''$ bolts. The bracing between the centre standards are of round iron $\frac{5}{8}''$ diameter.

The louvres are glazed with glass $\frac{1}{4}$ thick; the covering upon the rafters consists of best duchess slating, with a lap of 3 inches. They are secured to $1\frac{1}{4}$ inch boarding by stout copper nails. The boarding is cut into lengths, so as to break joint over the main principals only, and is ploughed and tongued with inch galvanised hoop iron. The boarding is fixed to $\frac{1}{2}$ inch deal curb on the backs of the main and intermediate principals, the curb being secured to the rafters by $\frac{3}{8}$ inch square-headed coach-screws, placed 9 inches apart, on alternate sides of the **T** iron, and is chamfered on the under side, and fitted into the longitudinal timbers (6 inch by 3 inch) at each end. The total weight of iron work in roof, exclusive of columns and screen at south end, is 900 tons; weight of iron work in roof, exclusive of columns, ·5 tons per square; boarding and slating ·45 tons; total weight per square ·95 tons. The cost, as per contract, and extras, including columns and screen, was £30,780, or about £17 2*s.* 7*d.* per square of 100 feet superficial.

LONDON, BRIGHTON, AND SOUTH COAST RAILWAY.

PIMLICO STATION.

SPECIFICATION OF ROOF.

Plates 1, 2, 3, 4, 5, 6, 7, and 8.

CAST AND WROUGHT IRON WORK.

The contractor to conform to all the conditions contained in the general specification. In estimating the weight of wrought-iron work an allowance of 5 per cent. to be made for waste, &c.

BASES, COLUMNS, AND BRACKETS.

The brick and stone foundations for carrying the columns will be constructed under another contract, and the stone bases will be sunk to receive the base plates of the columns, but the contractor will be required to provide and fix such base plates, together with the holding down bolts. The plates to be bedded solid upon the stone bases, and all voids to be filled up by running in best Portland cement grouting. The holding down bolts to be louissed into the stones, run with lead, and the plates securely fastened by nuts, as shewn on the drawing, numbered from 1 to 8 inclusive.

Each base plate to be provided with a bent discharge pipe, to be fixed as may be directed, for the purpose of conveying water from the roofs to the nearest drains.

The columns to be cast as shewn, and the bearing upon the base plates to be accurately formed by planing and fitting, and the equal distribution of the weight to be further secured by the interposition at the joint of a strip of 7 lbs. sheet lead, 3 inches in width.

The lugs upon the feet of the columns to be cast solid and bored out after they have been fitted upon the base plates; the latter to be cast with holes or not, as may be preferred, but to be bored out to the exact size to receive the bolts before fitting to the columns.

The heads of the columns to be turned true to receive the brackets both upon the upper surface, and upon the raised fillet inside, as shewn upon the drawing.

The brackets upon the top of the column to be accurately turned and fitted, and to be screwed thereto by means of $1\frac{1}{2}''$ bolts and nuts to each column.

The ornamental foliage in the spandril of the brackets to be finely cast and provided with projecting lugs, to admit of their being cast into the solid parts of the brackets.

The foliage forming the capital of the column to be fine castings, in two or more parts, as may be ordered, and to be securely connected with the columns by bolts, nuts, and screws, as shewn, in addition to a wrought-iron hoop $1\frac{1}{2}'' \times \frac{1}{2}''$ shrunk on hot immediately above the neck moulding or fillet of the column.

The brackets to be provided with proper chipping pieces for forming the joints, and to be securely connected together by the several bolts shown on the drawings, the bolt holes being carefully rimed out to the exact diameter of the bolts, and no packing to be allowed in any of the joints. The upper and lower bearing surfaces of the two main or column brackets to be turned up in the lathe, after being fitted and bolted together, and the axis to be vertical, and truly in line with those of the column and base plates, when fixed in place.

SCREEN AT SOUTH END.

At the south end of the station, adjoining the Eccleston Road Bridge, the space between the top of the parapet wall and the eaves of the last span of the roof to be filled up with an ornamental iron screen, as shewn upon drawing No. 2. The columns to be cast hollow, and to rest upon stone bases, or pilaster caps, forming the coping of the parapet wall. The cast-iron gutters, resting upon the columns, to be securely fitted thereto with water-tight joints, and to be constructed to carry the feet of the roof principals. The water from the gutters to pass down the columns into pipes, built into the brick pilasters, and the space between the columns to be filled up with ornamental cast work, as per drawing.

SHOES, GUTTERS, AND SMALL CASTINGS.

The feet of the principals forming the first bay of the roof at the northern end of the station, to rest in cast-iron shoes bolted down to timber framing, as shown on drawing No. 4.

The contractor to provide and fix such shoes with the holding-down bolts. Cast-iron gutters, in lengths of not less than 12 feet, to be provided and fixed upon the same timber framing, and to be securely bolted thereto, and to the shoes last specified, and, at convenient points, not more than 24 feet apart, 4-inch cast-iron rain-water bent pipes to be provided and fixed, to convey water from the gutters into the stack pipes, not included in this contract.

The joints of the gutters to be made perfectly water-tight, and to be so maintained during the whole term of the contract.

The shoes for carrying the feet of hip rafters and half principals to be provided and fixed upon the side walls and stone corbells in the hotel wall, being bolted through timber wall plates or louissed and run with lead, as the case may require, by and at the cost of the contractor.

TRUSSED GIRDERS.

The main support of the roof principals being dependant on the trussed girders, which are intended to run transversely across the station area, supported at points from 120 to 125 feet apart, the greatest care to be taken in their construction and fixing, and no deviation whatever from the working drawings, to be from time to time supplied, will be permitted upon any pretence.

The whole of the links forming the tie bars of the truss to be carefully forged and bored to an uniform gauge to receive the pins; the holes at the feet or lower ends of the struts and suspension bars, to be also bored to the same gauge, and the pins for connecting them all together to be accurately turned to fit such holes; the upper ends of the struts and bars to be rivetted to the compression plate, which shall be of wrought iron, of as long lengths as can be got, with sound butt joints securely connected by rivetting with proper cover plates.

The castings at each end of truss to be securely connected therewith as shown, and to be provided with ample chipping pieces, so that they may fit accurately butt and butt when bolted together, and upon the top of the column brackets—the bottom bearing surface to be planed, and the bolt holes bored out to fit those of the column brackets.

The whole of the wrought-iron work of each truss to be put together in its permanent position connected to the end castings, and properly tightened up to the ultimate strain intended to be thrown upon it, before the castings forming the gutters and carrying the roof principals, are fitted together or rivetted to the top compression plates.

The greatest care to be taken in the casting, filling, and fixing of the compound gutter, so as to secure perfectly water-tight butt joints, continuous surface contact between the cast and wrought metal, the correct distances between the shoes of each principal, regular fall from the centre each way to the columns, and lines true to the eye when seen from below.

The rivet holes, if cast in the gutters to be rimed or bored out to an uniform gauge, and holes to be drilled through the compression plates of the truss, to coincide accurately with them, after having been filled as before specified.

The longitudinal and cross joints of the gutter castings to be well rammed with iron cement after erection, and the bottom of the gutters, when thoroughly completed, to be finally paved over, for a width of 10 inches, with some preparation of asphalte to be hereafter approved.

The two sides of the gutter to be further secured together by means of wrought-iron distance pieces, placed at intervals of about 12½ feet, and bolted to the inner flanges of the gutter castings.

The castings at the ends of the trusses, resting on the side and hotel walls, to be cast in one, and specially arranged to convey the water from the gutters, and to deliver it into rain water heads and stack pipes (not included in this contract), but fixed, in some cases, at the back, and in others on the side or sides of such castings, as shown upon drawings. Bed plates to be provided and bolted down to the stone templates built into the walls; the surfaces of such bed plates, and the bearing surfaces of the truss castings, to be accurately planed, and bolted down one to the other, with proper allowance for expansion and contraction in the bolt holes, and with such other additional precautions to be subsequently ordered, but to be provided for and included in the amount of the tender for this contract.

In fixing the trusses, a portion of the weight to be thrown upon the column brackets, by the interposition of a packing of creosoted pitch pine cut to proper dimensions.

Ornamental castings to be provided and fixed, as shown by blue lines on drawing No. 4, at the upper and lower angles of each triangle, to conceal the rivets and bolt heads, and to give effect to the appearance of the girders; the design and mode of fixing of such ornaments, to be specially submitted to and approved by the engineer, before fixing, but the cost to be estimated and included in the amount of the tender and contract.

BRACES.

Bracing frames, or cross girders of wrought and cast iron, and of an ornamental character, to be provided and fixed longitudinally from column to column, and to be firmly secured to the ends of each trussed girder for the purpose of retaining them accurately in their places, and to neutralize any unequal thrust from the roof principals.

The upper and lower members of such girders to be formed of double angle iron, each welded into one length, and punched or drilled with holes of the correct size and proper positions to receive the bolts for connecting the struts and ties.

To be connected at both ends with the pockets cast on to the trussed girder pedestals, by means of steel keys and cotters, firmly tightened up when in their places, so as to throw all strain upon the struts and suspending bars, and to avoid any tensile strain upon the cast-iron diagonals.

The cast diagonals and ornamental cross bosses to be superior castings of the finest description, and to be very carefully fitted and fixed in accordance with drawing No. 6.

Proper provision to be made in spacing the bolt

holes for the variation in length of some of the spans, and the struts to be so fixed as to produce a camber of 2 inches in the top and bottom of the girder.

Cast-iron brackets to be provided and bolted to the timber framing of the screen at the north end of the station, for receiving the ends of the bracing frames abutting thereupon, provision to be made by forged iron for connecting such frames with the main trusses of the spans of irregular width at the south end of the station. No bracing frames to be fixed in the space immediately adjoining Eccleston Bridge.

ROOF PRINCIPALS AND HIP RAFTERS.

To be framed of cast and wrought iron, and fixed as shown on drawing No. 7.

The main principals to be fixed about 12½ feet apart, and to be constructed of T iron backs, punched for screwing down the deal curb, and to receive the several bolts and rivets, and with tie bars of round iron properly forged and finished to form the various connections as shown. The suspending rods to be of round iron, forged and finished as before, and the struts to be of the best patent welded gas tubing of 2 inches and 1½ inches, internal diameters. The heads of the struts to be fitted into cast-iron sockets, and secured thereto by pins upset so as to fill up countersunk holes in the former.

The feet to be furnished with cast-iron internal bushes, intended to form an abutment against the nuts working upon a wrought-iron screwed eye-bolt for the purposes of adjustment in length, and to form the connection with the tie suspending rods.

The feet of the principals to be secured to the lugs, cast on to the gutters by means of 1″ bolts and nuts, and the heads to be accurately fitted into the feet of the ridge standards hereinafter specified.

Ornamental castings to be provided and fixed as shown to cover the connecting plates and bolts at the joints in the tie bars.

The connecting plates to be of best ⅜″ boiler plate, shaped, punched, and fixed, as shown on drawing.

The intermediate principals to be constructed of T iron, the feet to be bolted to the lugs, cast on the gutters as before, and the heads to be bolted up to the underside of the castings intended to carry the louvre standards.

To be undertrussed at the centre by means of a light cast-iron saddle or bracket, bolted to the T iron back, and supported on a round iron tension rod, secured at each end to the alternate main principals.

The hipped principals and rafters to be constructed in every respect similar to the main ones, and to be provided with cast-iron shoes for fixing upon the walls, and cast bosses and wrought-iron joint plates to cover and form the several connections.

For the southernmost bay, adjoining Eccleston Bridge, the spans will diminish gradually from feet to feet, and the principals will be covered with boarding and slating, only without ventilators or skylights. The strength of iron to be reduced proportionably in accordance with working drawings, to be hereafter provided, and the necessary alterations in the several details to be made as may be ordered without extra charge.

LOUVRES AND SKYLIGHTS.

The louvre standards to be of cast iron, and to be accurately bolted on to cast-iron girders, resting at each end upon the main principals. To be provided with bolt holes for receiving the sheet-iron louvre bolts, and the upper castings forming the sash frame.

The louvre standard girders resting upon the T iron principals, and the sash frame girders supported on the louvre standards, to be securely bolted together and to be cast of the proper lengths, and accurately fitted at the joints, so as to make a perfect and workmanlike job. The sash frame girders to be cast with pockets, as shown, to receive the feet of the wrought-iron sash bars, and with a raised fillet on the upper side against which the glass may close.

The louvre plates to be of galvanised sheet iron, ⅛-inch thick, of sufficient length to fit tight between the standards, and bent up along the edges, as shown, and to be connected with the standards by ⅜″ bolts, four to each sheet.

The ridge plates or girders to be of cast iron, with pockets to receive the heads of the sash bars, and lugs on the under side for the wind-ties.

To be bolted to one another, and to the ridge standards over the main principals, and the end joints to be chipped and fitted, so as to form perfectly water-tight joints.

The ridge standards to be of cast iron, as shown on drawing No. 8; secured at the bottom by four ⅜″ bolts to the T iron backs of the main principals, the feet forming the heads of such principals, and cast with hollow sockets to receive them, and with bolt holes for the diagonal braces or wind-ties.

These wind-ties to be of round iron, and to extend from the head of each main principal both ways to the top of each ridge, standards being there secured by means of ⅜″ bolts to the lugs cast on to the underside of the ridge girders.

The sash bars to be of rolled iron, to the section shown on drawing No. 8, and to be accurately fitted at both ends into the pockets cast to receive them upon the ridge sash-frame girders. The joints to be made, with white lead and oil, perfectly water-tight.

Extra skylights to be provided and fixed, as shown on general plan, drawing No. 1, to both sides of the northernmost bay, and to each of the western hipped ends of the five bays, adjoining the hotel.

The sash frames and bars of such lights to be of wood; each frame to be 9 feet in length within the

framing, and of such width as to joint on each main intermediate principal.

The top and bottom rails to be $9' \times 3''$; side ditto, $5' \times 3''$, with sash-bars $3' \times 1\frac{1}{2}''$, morticed and mitred to frames, and the whole to be securely screwed down to the T and L iron of the principals.

Sash-bars to be spaced about 15 inches, centre to centre.

The top rail of each frame to be stiffened on the under side by lengths of L iron $3' \times 3'' \times \frac{3}{8}''$, expressly provided for the purpose, turned up at each end, and then fastened to the web of the T iron principals with No. $2\frac{1}{2}''$ rivets.

The bottom rails to be secured to the C. I. gutters with $\frac{1}{2}$-inch coach screws, 15 inches apart.

The sash bars at the centre of their length to be supported on flat iron $1\frac{1}{2}' \times \frac{1}{4}''$, screwed to the underside of every bar, and to the side rails of frames.

The longitudinal joints of each frame over the principals to be rebated and lapped $1\frac{1}{2}$ inches, grooved on the upper side, and covered with a weathered fillet out of $5' \times 2\frac{1}{2}''$, securely nailed down over the rebated joints, the joints and underside of the covering fillets having been first well coated with white lead and oil.

5 lbs. lead flashing, 10 inches wide, to be nailed to the bottom rails to cover the joints between them and the gutters.

BUILDER'S WORK.

The whole of the builder's work generally, including the carpentry, slating, plumbing, glazing, painting, &c., to be carried out in strict conformity, both as to materials and workmanship, with the several conditions relating to each trade contained in the general specification.

CARPENTER AND JOINER.

The boarding for the slating to be $1\frac{1}{4}''$ thick, cut from battens of the best quality, wrought and beaded on the underside, ploughed and tongued with inch galvanised hoop iron, and cut to such lengths as to break joint over the main principals only.

The $1\frac{1}{2}$-inch deal curb on the backs of the main and intermediate principals to be secured thereto by $\frac{3}{8}$-inch square-headed coach screws, placed $9''$ apart on alternate sides of the T iron, and to be wrought, and chamfered on the underside, and tenoned into the longitudinal timbers or styles at each end.

The styles at the feet of the louvre standards and those adjoining the gutters to be wrought where seen, chamfered, grooved for iron tonguing, mitred to chamfered cubes, and morticed to receive them.

The ridge of the southernmost span to be of deal $4' \times 1\frac{1}{4}''$ wrought, and chamfered where seen with $3''$ rounded roll for lead.

All ridges to hips and principals where covered with lead to have $3''$ rounded rolls.

All lead gutters adjoining walls and buildings to be laid on $1\frac{1}{4}''$ gutter boards, with proper bearers laid to fall 1 inch in 15 feet, and well secured to the main timbers of the framing.

The ends of the louvre ventilators to be filled up with $2''$ deal spandril framing, wrought, beaded, and ploughed, to receive $1''$ ploughed iron-tongued boarding, wrought and beaded both sides.

SLATER.

The whole of the roof (with the exception of those parts occupied by the skylights and lead) to be covered with the best duchess slating, of an uniform and approved colour, carefully laid with $3''$ lap, and each slate securely fixed to the boarding with two stout copper nails.

PLUMBER.

The whole of the gutters to be laid with 7 lbs. lead, of such width as may be considered necessary in the several situations.

Wall and step flashings of 5 lbs. lead, and 6" wide, to be provided and properly laid wherever ordered.

The whole of the ridges to be covered with 6 lbs. lead, as per general specification.

GLAZIER.

The whole of the skylights to be glazed with Hartley's Patent Ribbed Glass, $\frac{1}{4}''$ thick; each sheet to run from 3 to 4 feet in length, and to be well bedded in putty, with $2\frac{1}{2}''$ lap and copper clips to each, to prevent displacement before the putty has set.

PAINTER.

The whole of the woodwork to be properly knotted, primed, and stopped, and then to receive, at such times as may be approved, three coats of plain oil colours of any tints that may be directed.

The whole of the cast and wrought-iron work throughout to receive, after inspection and approval, but before leaving the contractors' works, one good coat of best red lead and oil paint, and a second coat of Todd's Patent Protoxide Paint, after fixing. Subsequently, and at such times and intervals as may be directed by the engineer, the painting to be completed with two coats of best oil colour, the one plain, and the other of any tints or colours that may be directed.

Contractors to include in the amount of their tenders an allowance for any extra cost they may incur in experimental painting, or in picking out portions of wood and ironwork in divers colours, but in plain lines and patterns.

Bronzing and graining, if ordered, to be allowed for as extra works.

PROVISIONS, ETC.

Contractors to include in the amount of their tenders a sum of £1,000 to cover the cost of any

alterations in, or additions to, the works to be contracted for; the value of such additions or alterations to be paid or deducted, as the case may require, in accordance with the schedule of prices attached to each tender. Should no such additions or alteration be ordered, or only a portion thereof, the entire sum of £1,000, or a proportional part, to be deducted, and withheld from the amount of the contract, together with any further deductions that may be due to the Company, either on account of reductions in the amount or value of works executed, or of penalties incurred by the contractor or otherwise.

ERECTION, COMPLETION, AND MAINTENANCE.

The contractor to be prepared to submit the patterns of all the heavy castings for approval within two weeks after the acceptance of his tender, and within a week afterwards to furnish the Company with an accurate model in wood of the base plates, for the purpose of working the stone bases to receive the castings.

Within six weeks after the acceptance of his tender, the contractor to commence delivery and fixing of the base plates and columns, which shall commence at the north end of the eastern row, and proceed regularly southward and westward, until the whole are fixed.

SOUTHPORT PIER.

DESCRIPTION.

Plates 9 and 10.

THIS pier was erected from a design, furnished by Mr. Brunlees, Mem. Inst. C.E., by Messrs. Galloway of Manchester, the contractors, under the superintendence of Mr. Hooper, the resident engineer.

It is 1,200 yards in length, and the super-structure is 15 feet wide between the handrails.

The girders carrying the footway rest upon a series of piers, each pier being formed by three cast-iron columns; each of these columns is cast in three lengths. The lowest divisions of each column are cast in lengths of 8 and 10 feet, and are sunk into the sand to the depth of 7 and 9 feet respectively. They are 7 inches in external diameter, and 5⅝″ in internal diameter, and are provided at the lower end with circular discs of 1′ 6″ diameter, and 1·75 square feet area, to form a bearing surface; each disc has a small hole in the centre to facilitate the sinking. The joint connecting the piles at the top of the lower one, is of the socket form 8 inches deep, and made good round the column with iron cement, while the upper lengths are connected by a flange joint turned in the lathe and accurately fitted.

The upper lengths have cast-iron bearing plates 1′ 2″ × 6½″ to support the ends of the girders, with four holes to receive the bolts which secure them to the girder. These holes are 1″ inch diameter, and are cast oval to allow for expansion and contraction.

The three columns forming the pier are braced transversely by means of diagonal tie rods 1¼″ in diameter, which reach from the level of the sands to the under side of the girders carrying the roadway. The method adopted for sinking the piles was the plan used with such success by Mr. Brunlees in the Kent and Leven Viaducts, but in this case with much greater advantages. A slight description of this method may not be out of place. A wrought-iron pipe was passed down the column through the hole left in the disc, and forced about 4 inches into the sand; the top of this pipe was connected by a flexible hose to a temporary pipe in connection with the Water Company's mains. The water thus obtained exerted a pressure of about 50 lbs. per inch, which, coupled with an alternating motion which was given to the pile, was quite sufficient to loosen the sand around the disc, and, of course, at the same time allow the pile to sink.

The piles were guided by an ordinary piling machine. By these means, about six or seven piles were sunk every twenty-four hours, and by taking advantage of the water supplied by the Water Company, instead of using pontoons supplied with a donkey engine of 2-horse power, as at Leven and Kent, the cost of sinking was reduced from 2*s.* 6*d.* per foot to 4½*d.* per foot.

The columns, after the pressure of water had been removed for about five minutes, were tested with a load 12 tons each, or 7 tons per square foot; this weight, however, did not cause any perceptible settlement. Double piers are introduced in three places, which have the effect of breaking the continuity of the structure, and, at the same time, give stability to the pier in the direction of its length; they also afford an opportunity of projecting angle iron brackets, to support seats clear of the footway.

The superstructure consists of three rows of longitudinal lattice girders, in bays of 50 feet in length and 3 feet deep, having a bearing in the clear of 48 feet 10 inches. At the sea end of the pier there is a platform 100 feet long and 32 feet wide, with a semicircular head in the centre and in a line with the pier, at right

angles to the line of footway. Access to the sands or to the boats is obtained by means of two light cast-iron staircases, supported on wrought-iron raking lattice girders 2 feet 6 inches deep. The centre girder having to perform double the duty of each of the two outside girders, the extra strength is obtained by the addition of top and bottom plates. The dimensions of these plates are, the top plate $9 \times \frac{1}{4}$ and the bottom $6\frac{1}{2}'' \times \frac{3}{8}''$.

The calculated breaking weight of this girder with distributed load is 60 tons.

One of the outside girders was tested at the works to 27 tons of equally distributed weight, and also with 13·71 tons at the centre, and three of them were capable of supporting a weight of 110 tons, being only 10 tons less than the calculated breaking weight, while the greatest weight that can possibly come on one bay is 44 tons.

The second bay from the shore end was tested by a load of 35 tons equally distributed, and the mean deflection of the three girders in twenty-four hours was $1\frac{1}{4}''$ inches, and, on the load being removed, the permanent set was half-an-inch.

The girders in each bay are stiffened transversely at each end and in the middle by diagonal bracing of angle iron with a T iron purlin at the foot, $4'' \times 2\frac{1}{2}''$ and $\frac{3}{4}''$ thick, the purlin alone being used in the two intermediate spaces. The rivets used for riveting the bracing and the purlins to the girders are $\frac{5}{8}''$ of an inch in diameter.

The footway is formed of spruce deals, 7 inches by 3 inches in section, laid transversely with spaces of 1 inch between each plank to prevent the lodgment of water on the upper surface.

Each plank is secured to the girders by six cup-headed bolts, $\frac{3}{4}$th of an inch in diameter, the two ends beyond the outside girders being finished with a half round nosing piece 3 inches deep. The handrail is formed by hollow cast-iron standards, tapering upwards from 3 inches to $2\frac{1}{2}''$ inches external diameter, the thickness of the metal being $\frac{3}{8}$ of an inch. These cast-iron standards are 6′ 3″ apart from centre to centre, and are bolted to the girders by four bolts $\frac{1}{2}''$ in diameter. They are connected by the top rail, which is formed of T iron $2'' \times 2'' \times \frac{1}{4}''$ thick, surmounted by a rounded capping of red deal $4'' \times 1\frac{1}{2}$ in section, screwed on to the under side of the top web of the T iron, and also by two horizontal bars $1\frac{1}{2}'' \times \frac{5}{16}''$ in section. To these bars, vertical rods of round iron $\frac{3}{8}''$ in diameter are fastened at intervals of 6 inches.

The whole of the cast-iron work in the piers was boiled for one hour in a composition of tar and asphalte; the wrought-iron work and cast-iron standards for the handrail were painted with one coat of red lead when put together, and with two coats of stone colour when erected. The deals forming the footway were dipped in boiling coal tar, and sanded over on the upper surface. The scantling of iron used in the girders is as follows:—

IN OUTSIDE AND INSIDE GIRDERS.

The two angle irons at the top and bottom, each	$3\frac{1}{2}'' \times 3'' \times \frac{3}{8}''$
The vertical T irons	$4'' \times 2\frac{1}{2}'' \times \frac{3}{8}''$
The lattice bars at the ends	$2\frac{1}{2}'' \times \frac{1}{2}''$
The lattice bars at the middle	$2\frac{1}{2}'' \times \frac{1}{2}''$

The weight of wrought iron in one 50-feet span is:

	Tons. cwt. qrs. lbs.	Tons. cwt. qrs. lbs.
Two outside girders, each	1 1 0 0 ...	2 2 0 0
One middle	1 8 3 0 ...	1 8 3 0
Two diagonal column ties	0 0 3 10 ...	0 1 2 20
T and L iron bracing	...	0 6 0 21
Handrail	...	0 6 1 19
		4 5 0 4

The weight of cast iron in each bay is:

	Tons. cwt. qrs. lbs.
Three columns or piles	1 11 1 7
Sixteen standards for handrail, 40 lbs. each	0 5 2 24
	1 17 0 3

	Cwt. qrs. lbs.
Weight of an 8 feet pile	3 2 12
Weight of a 10 feet pile	4 1 7

The estimated cost of the pier, including toll-house, approaches from the promenade, &c., was £10,400. It has been completed for £9,135, being at the rate of £7 12*s.* 3*d.* per lineal yard.

The chief advantages which are claimed for this mode of construction are:—

1st. The great saving obtained by the method adopted for sinking the piles;

2nd. The small resistance offered to the action of the wind and waves;

3rd. The expeditious manner of obtaining a solid foundation;

4th. Similarity of parts; thus reducing the expenditure very considerably; and

5th. The employment of a material which cannot be affected by marine insects, as in the case of Southend and Whitstable, where a large amount is annually expended to preserve the piers.

WESTMINSTER BRIDGE.

From a parliamentary return published in December, 1862, the amount expended on the works connected with this bridge was—

	£	*s.*	*d.*
To contractors	145,057	18	5
To other parties	248,132	0	9
Making a total of	393,189	19	2

The length is 1,160 feet 3 inches, and the width between the parapets 84 feet 2 inches.

The cost would therefore be £338 15*s.* per foot run, or about £4 per foot superficial, whereas, in the late Sir William Molesworth's report, the estimate cost was stated to be £235,000, or £2 8*s.* 6*d.* per foot superficial. In addition to the sum of £393,189 19*s.* 2*d.*, there has been £109,054 4*s.* 9*d.* paid for approaches. The whole amount has been supplied from property belonging to the Westminster Bridge Commissioners and Votes of Parliament.

LOCOMOTIVE PRACTICE.—RAILWAYS.

WITHIN the past ten years it may be said that little real improvement has taken place in the design or construction of the locomotives used on railways, though much has been done in the way of using materials of a stronger and better quality, such for instance as the tires now made without a weld, and other portions now made of steel, manufactured by Krupp and others, the improved axles, &c., &c., from which greater durability in working, and less liability to accident are secured.

The general tendency of the present locomotive practice seems, however, to be towards heavier engines, outside cylinders, and wheels of large diameter. It is doubtful whether the increasing weight of the locomotive now in use, which, it may be remembered, is considered necessary from the heavy trains now run, does not do more harm than good, by increasing the wear and tear of the permanent way, thereby rendering the liability to accident much greater, and increasing also the frequency of the repairs of the locomotive, already heavy enough, caused by the great weight of the engine itself. The outside cylinder arrangement appears to have been rendered needful by the small space between the rails of the ordinary narrow gauge system rendering it rather difficult to get the machinery required in engines of the large power now employed comfortably together between the wheels; added to which was the liability to fracture, and the cost of replacing the crank shafts when broken, to say nothing of the height to which the centre of gravity was raised when wheels of large diameter were used with inside cylinders.

It was for a long time objected that the employment of outside cylinders increased the liability of engines to leave the rails, and that engines so constructed were not so safe as inside cylinder engines. No doubt, in some of the earlier engines of this description, where balancing of the running gear was neglected, or the springs were not sufficiently stiff, such an argument would hold good; but now that the running parts are carefully counterbalanced, the springing better attended to, and the centre of gravity kept low down, outside cylinder engines may be considered far safer than the inside cylinder arrangement. We have travelled at very high speeds on outside cylinder engines, with far less motion and disturbance than on inside cylinder engines; and the very general use of this plan in many of the leading English and greater part of the Foreign railways, seems to show that they possess in practice the advantages that theory accords to them. The employment of the "bogie," or its later arrangement known as the "Bissell" truck, might advantageously receive greater attention, especially as the present tendency of railway engineers is to increase the sharpness of the curves in the branches or new lines now being constructed, on some of which curves of 15 chains radius or less are introduced. If it is remembered that with a curve of 15 chains, an 18′ rail requires to be bent half-an-inch out of the straight line, and that an engine with a 16′ or 18′ wheel base, the axles fixed on a rigid framework, and the wheels keyed fast on the axles, has to pass frequently at a good speed round this curve, a tolerable idea may be formed of the strain thrown on the road, and the wear and tear of tires.

The employment of the "bogie" or "Bissell truck," which is so universal in America, both for engines and carriages, would diminish greatly the wear and tear both of road and engine, and in a corresponding degree increase the safety of railway travelling. An objection has been raised against the use of the "bogie" that it would not be safe to use on inclines; but in America it has been found that on long gradients of 1 in 43 they give no trouble whatever. Mr. Cowan, the locomotive superintendent of the Great North of Scotland Railway, has introduced them on that line, which has both sharp curves and heavy gradients, and finds them give the greatest satisfaction, being well adapted for the line, and far better in working than the old class of engine. On the Great Eastern and North London Railways "bogie" engines are in use, and their employment is found to conduce considerably to the durability of the tires, and to lessen the wear and tear of the engine generally. On the Bristol and Exeter Railway double bogie tank engines, or engines with a bogie at each end, have been in use for many years to run the passenger trains, and have been found very successful. Coupled engines, with single bogies, for goods trains, have also been in use on the same line for a long period.

IMPROVEMENTS.

The direction the attempts to improve locomotives has taken, has been chiefly that of trying to reduce the cost of running them, and the methods by which it has been sought to attain this end, may be summed up as follows:—

1. Coal burning, or the substitution of raw coal in place of coke, so as to save the difference in cost of coal and coke.

2. Smoke prevention, or rather the employment of means to prevent the coal burned in the fire boxes producing the nuisance of smoke.

3. Heating the feed water by the waste steam, thus

avoiding the loss of the heat carried off by the steam after it has done its work in the cylinders.

4. Balancing the reciprocating and revolving parts of the engine, whereby the wear and tear of road and engine are considerably reduced, and the safe maintenance of high speeds rendered practicable.

5. Superheating the steam on its way to the cylinders, so as to maintain its normal heat and reduce the loss of power caused by condensation.

COAL BURNING.

In 1854, Mr. Joseph Beattie, locomotive superintendent of the London and South Western Railway, began to alter the engines on that line so as to adapt them for smokeless coal burning, and thereby obtain the advantage of the difference in cost between coal and coke, which latter is very expensive in the neighbourhood of London. Since this period, the use of coal in place of coke, throughout the various lines in Great Britain, has become quite general, and this is entirely due to the success which attended the efforts of Mr. Beattie to accomplish this end. As a rule, there is no one particular plan of more extended use than another, each locomotive engineer having some peculiar system or modification of his own, which he considers far superior to any other, and in consequence, each plan is confined, or nearly so, to its peculiar line.

So far back as 1837, Messrs. Gray and Chanter had endeavoured to use coal in the fire-boxes of locomotives, and thus save the waste of heat which always attends the operation of coke making, and these attempts were again renewed in 1839. They employed a fire-box divided into two parts, in one of which coal was burned and in the other coke, and a steam jet and air tubes open at one end to the air in the walls of the fire-box. It does not seem, however, that their system was brought into any notoriety, or that it can be considered other than an experiment. Mr. Dewrance, in 1845, attempted to bring the use of coal into general employment, using a fire-box so arranged as to have a combustion chamber. In 1856, Messrs. Dubs and Douglas employed a mid-feather so arranged as to deflect the smoke and products of combustion back over the burning fuel, and thus, as they expected, consume the smoke. The various plans or modifications that have been made for coal burning in locomotives, are so numerous that it would require considerable space to be given to their description; we shall, however, from time to time, when illustrating the various improved locomotives, give full descriptions of the systems used in each.

It may be taken as a rule, that one pound of coal burned in the locomotive with the best arranged system for preventing smoke, gives an equal or rather higher duty than one pound of coke. Mr. D. K. Clark, C.E., in his paper on "Coal-burning in Locomotives," read before the Inst. C.E., May 1, 1860, says, in contrasting the three systems of extended fire-box locomotives, that "with trains of nearly equal gross weight, 102 to 116 tons of engine, tender, and train, and at nearly equal speeds, Mr. M'Connell's system consumes 35½ lbs. of coal per mile; Mr. Beattie's, 24 lbs. (with feed-water heater shut off); and Mr. Cudworth's, 26 lbs.: or per ton gross, Mr. M'Connell's system consumes 0·31 lbs.; Mr. Beattie's, 0·235; and Mr. Cudworth's, 0·225 lbs. The evaporative powers rank in the same order; *i. e.*, Mr. M'Connell's evaporates 5·9 lbs. of water per pound of coal; Mr. Beattie's, 8·31 lbs.; and Mr. Cudworth's, 8·6 lbs. The excellence of Mr. Beattie's and Mr. Cudworth's systems is to be ascribed to the proximity of the radiant heating surface to the fuel and the flame; and in both systems the steam is well kept up." In comparing coke with coal on similar duty, Mr. Clark found that, whilst Mr. M'Connell uses one-half more coal than coke, Mr. Cudworth employs on the whole rather less coal than coke, the general average being 27·3 lbs. of coke against 25·8 lbs. of coking coal per mile, or 5½ per cent. less coal than coke. It was also observed that coking coal ranked higher than the other coal tried—Lord Ward's coal and Ruabon coal—of which the consumption would be greater than that of coke.

Mr. Clark carefully examined the working of those plans for burning coal which were applied to the ordinary coke fire-box, without requiring a reconstruction of the fire-box, or an engine specially built. Mr. Yarrow's plan, as used on the Scottish North Eastern, consumes 26·8 lbs. of Scotch coal against 22·1 lbs. of coke per mile, doing the same duty, giving an excess of 4·7 lbs. or 21 per cent. more coal than coke. Mr. Jenkins's, on the Lancashire and Yorkshire, uses 30·35 lbs. of coal against 32·43 lbs. of coke, or 6 per cent. less coal than coke. When this system was tried on the London and Brighton Railway it used 6·4 lbs., or about 23 per cent. more coal than coke. Mr. Lee's system, on the same line, used 5 lbs. or about 20 per cent. more coal than coke; and Mr. D. K. Clark's steam inducted air currents, when tried on the same engine upon which Mr. Jenkins's system had been used, burnt only 2·1 lbs. or about 7½ per cent. more coal than coke. In the engines used on the Great North of Scotland Railway, where this plan has been applied to all the engines, and on the Londonderry and Enniskillen Railway, it was found on the former line that 14·4 lbs. of coking coal were used against 16·28 lbs. of coke per mile, in a similar engine doing similar duty, during a period of twelve months, giving a consumption of 11½ per cent. less coal than coke. There can be no doubt that, however good any system of smokeless coal-burning may be, an important and desirable point is, that it should be easily manageable; for without this advantage it becomes an evil, inasmuch

as it frequently requires the attention of the men in charge, probably just as their attention is required in another direction, and by this means it may become an element of danger, as well as lose much of its efficiency and other advantages. Of the desirability of cheapness in application, freedom from wear and tear, and facility in repairing, in any system used for coal-burning, there cannot be the least doubt; and it is also desirable that the economy of heating the feed water for the boiler by means of the waste steam should be more attended to; the economy and advantage of this are proved to be about 12 per cent.—an amount certainly worth taking into account, but which at the present is sadly neglected.

SMOKE PREVENTION.

This has been sought to be obtained in various ways, many of which, it may be remarked, have shown a great want of that knowledge of the substance to be worked on, which is required for the successful carrying out of such an undertaking. In adapting the various plans which have been used for this purpose, to locomotives already in use, some have required a simple addition of a few accessories to the existing fire-box; others have required an additional fire-box; others a new fire-box altogether; and in some an entire reconstruction of the fire-box and boiler is necessary. In some plans the smoke is made to pass over or through heated bricks or tiles with the intention of consuming it. In others, the use of two long narrow fire-boxes with a sloping grate is required; the green coal being supposed to be put in the front and, as ignited, pushed forward, and fresh coal supplied as before; in this case it is supposed that the products of combustion by passing over the ignited coal would be further heated, and the smoke consumed. Another plan is the use of a slab or plate of cast-iron, with its front edge curved over and downwards, and perforated with small holes, which is bolted in an inclined position against the tube-plate in the fire-box, the design being to deflect the product of combustion back over the fire and thus prevent the formation of smoke, air being supplied through small tubes in the walls of the fire-box, which can be closed by *sliding* dampers when desired. In practice it has been found that these iron slabs are quickly destroyed by the intense heat of the furnace, and they are now employing fire-clay for this purpose. Another plan is the use of a plate, deflector, or shovel as it is termed, which is placed in the furnace doorway, and projects down to within a few inches of the surface of the burning fuel, the design being to get the air drawn in by the blast to mix with the products of combustion as close to the surface of the hot fuel as possible, and it is then further deflected again by a brick arch projecting about a third of the length of the fire-box from the front tube plate, just below the bottom row of tubes. In another plan, the air is admitted through two square apertures in the front of the fire-box, and a brick arch is turned across the front of the box, under which the air passes before going through the tubes. These apertures are regulated by doors or dampers. Another plan is that of blowing steam on to the fire through roses in the top corners of the fire-box, in the hope of preventing the smoke being formed, or of consuming it when formed. Some use a portion of the lower tubes in the boiler as air tubes, leaving the smoke-box end of the tubes open to the atmosphere, an ingenious arrangement for keeping the lower part of the boiler barrel from overheating. All the plans named are more or less imperfect and objectionable, some from their expense and complication, others from their inefficiency, and all are continually needing repair. The most complete, simple, and efficient plan for burning coal without smoke is that of Mr. D. K. Clark, C.E., who introduced it some years since. The principle is that of inducting, by means of a minute jet of steam through a row of small holes in the sides of the fire-box, the amount of air needed to prevent the formation of smoke, and cause perfect combustion to take place. This air is forcibly mixed and intermingled with the products of combustion just above the fire in the box, and where the heat is greatest, thus entirely preventing the formation of smoke. A great advantage this plan possesses over all others is its simplicity and ease of application, to which may be added small cost in the first instance, and no necessity for repairs, nor does it in any way need a reconstruction of engine; we have travelled with all the systems in use for this purpose, but have found none in any degree approaching this one. On the Great North of Scotland Railway all the engines have been fitted with it, and it has been applied to numerous engines for the Indian railways and elsewhere. In all the engines where coal is used and this system is not employed, a powerful blower or steam jet is used in the funnel, to try and mitigate the smoke, but this is a mistake, as it draws the air through the fire, freshening it up, raising the steam which either blows to waste or is turned into the tank, and fuel is thus burned with no useful result, whilst by Mr. Clark's plan the smoke is perfectly *under control*, and the air jets can be used as a damper when the engine is standing. On some lines, perforated fire-doors are used, but they are of very little use, and any one living near the coal-burning lines in the neighbourhood of London, the system used on each of which is said to be perfect, will quickly be able to see how little the smoke prohibition is attended to, and how deficient the plans employed are, in preventing smoke.

FEED WATER.

In 1854, at a period when the engines on the London and South Western Railway were being arranged so as to use coal instead of coke, Mr. J. Beattie, the loco-

motive superintendent designed a plan by which the steam, after it had done its work in the cylinders, should, on passing into the atmosphere, contribute a great portion of its useless heat to the feed-water before it passed into the boiler; the results of this plan were most successful, and a great saving was the consequence, amounting to over 12 per cent. on the duty obtained from the coal without its use. We have frequently travelled with the engines fitted with Mr. Beattie's feed heater, and whilst on the run placed a thermometer in the tank at various times on the journey, and found the temperature raised to 190° and 210° by the heat of the waste steam, at which temperature it was pumped into the boiler.

On the 23rd of March we had an opportunity of trying the effects of this feed-water heater on the express to Southampton, and the following were the results obtained:—The train consisted of eighteen carriages, and the engine, the "Eagle," started with a full tank, the temperature of the water in it being 89°, caused by the steam having been blown into the tank whilst the engine was standing; the pressure being 130 lbs. in the boiler. During the journey, the heat of the feed-water, after it had passed through the heater, was found to be 210°, the water running through a small cistern in which a thermometer could be placed; and at this temperature, the surplus which was not required for the boiler passed into the tank, and when tried at each 10 miles during the run, was found to rise gradually from 89° to 105°, 112°, 130° up to 150°, which last temperature it had reached in the course of an hour, when it was required to fill the tank, and by this the temperature of the whole was lowered to 75°. Two tons of coal were weighed on to the engine, and of this, four cwts. were used in raising steam, and at the end of the return trip, with fourteen carriages, there remained five cwts., giving a consumption of about 19 lbs. per mile run. The engine kept steam very well; it never having dropped below 80 lbs., nor exceeded 140 lbs., and the gear was in the third notch over the greater part of the road. The weather was fine, the rails dry, and the wind light, the temperature being 59°. The journey, both ways, was performed in a minute or two under the time; excellent time being kept at all stations. The coal used was mixed, one-third Welch and two-thirds Windleworth; no smoke was produced, and there was no priming, or other inconvenience.

For a long time previous to Mr. Beattie's plan the steam that would have blown to waste whilst the engine was standing, was turned by means of a pipe and stop-cock into the tank in the tender, where it raised the temperature of the water nearly up to the boiling point, and of course, when pumped at this temperature into the boiler, produced a considerable saving in the fuel used.

At the present time it may be remarked, that the economy obtained by feed-water heating is not so generally sought as formerly, more particularly since the introduction of the injector, the use of which most locomotive managers seem to consider much more economical and efficient than the pumps used on locomotives. Whatever advantages this injector may possess, it has one most serious disadvantage which is fatal to its employment wherever economy is sought, and that is, that it will not inject the feed-water if it be raised to 100°; added to this, it is a very ticklish instrument, far from reliable, and the substitution of one, or even two of them, for the pumps ordinarily used in locomotives, does not in any way conduce to economy in working.

We believe the chief reason for the adoption of the injector was the expectation that it would prove more economical in working and maintenance than the pump; but if it be borne in mind that its use *prevents* the employment of hot feed and its attendant saving, and knowing the little trouble given by well-made pumps, we do not think that sufficient reason has yet been given for its exclusive adoption. Mr. D. K. Clark, C.E., some few years since, designed a very neat, simple, and efficient feed-water heater applicable to engines of all kinds, which, when employed on a twenty-horse stationary engine, gave a saving of 12 per cent. This, no doubt, from its portability, cheapness, and ease of application, would have been much more generally used had not the injector mania come on just at its introduction. We believe, however, that economy will again become the order of the day, and that feed-water heating will be of universal employment.

BALANCING.

The first person who appears to have studied and advocated the balancing of locomotives was Mr. George Heaton, of Birmingham, a well known and skilful engineer. It was constantly found, some twenty years ago, that when an engine was run at speed, the motion of the engine was so compounded of pitching, rolling, and twisting, that it was not safe to maintain the speed at which she was running when this movement commenced; and, on many occasions, though tolerably safe at a low speed, unbalanced engines had left the rails for apparently no assignable reason.

It is well known that any quick moving, unbalanced drill, or piece of wood or other material, in a turning lathe, for example, if driven round rapidly, would shake everything in a tremendous manner; but balance it properly, and it may be run at any speed without fear. In some of the small rotating cutters, revolving at several thousand turns in a minute—which are used in wood carving machinery—a very little fault in the balancing has caused such a disturbance, that it has now become a matter of primary importance to have them regulated with the most careful exactitude.

Such being the case with so small an object as the drill, or the material in a turning lathe, it will be at once evident how much more needful this balancing must be in a locomotive of some 30 or more tons weight, when travelling at say fifty miles an hour. Here we have the direction of the momentum of the pistons, rods, cranks, &c., constantly changing at the rate of some two or three hundred times in a minute, which, if the moving parts be unbalanced, the springs of the engine be not exactly of the required stiffness, and the road be a little out of order, cannot fail to cause such a plunging and twisting of the engine as does great injury to the engine itself, and causes each inequality in the road to become greater as the engine passes it, and not unfrequently, also, causes the engine to leave the rails. A goods engine which, when unbalanced, was tried on the road at a speed of 30 miles an hour, behaved at that speed in such a manner that it was impossible to continue running; but this same engine, when properly balanced, and put in the trim all engines require—if the work is to be done in a proper manner—could be run at fifty miles an hour with perfect ease and steadiness.

In some engines the counterbalance weight is neatly forged on the rim of the wheel, making a less unsightly job than the great lump of metal used for this purpose when placed between the spokes. In the International Exhibition of 1862, a good example of this plan was seen in the engine by Messrs. Neilson & Co. Some makers cast the bosses of the wheels with a greater mass of metal on one side than the other, which, when placed on opposition to the crank, was intended to balance the rods, &c.

However this balancing may be carried out, there can be no question of its importance, and the desirability of its use; and no engine should be allowed to run before being slung, and the moving parts carefully placed in balance. In order to obtain this desirable end, engines have been designed with four cylinders, two to each driving wheel, so arranged that no disturbance should be caused by the reciprocations of the pistons; one of them was in the International Exhibition of 1862, and was designed and constructed by Mr. Haswell, of the Imperial Austrian Locomotive Factories. It is stated that this engine, when blocked up, had been run at a speed of nearly 100 miles an hour, without any disturbance being caused by this rapidity of motion. The following are the results of the trials with this engine which were made—first, by lifting the engine so that the driving wheels were off the rails; and secondly, by trips on the line with a train.

First. The engine being slung, so that the driving wheels were 2½ inches above the metals, and the engine having only the leading pair on the rails, steam was put on, and the following table gives the results:—

No. of Trials.	Steam Pressure.	Position of Regulator.	Position of Reversing Lever.	Revolutions per minute.	Piston Feet per minute.	Speed of Locomotive in miles per hour.	Disturbing Motion in inches.	
	lbs.						horiz.	vertic.
1	77·2	4th notch	1st notch adm. 65 per cent.	220	15·2	52·95	0·034	0·130
2	82·7	„ „	1st notch	222	15·3	53·43	0·043	0·173
3	„	„ „	„ „	240	16·6	57·76	0·043	0·259
4	„	6th „	„ „	120	8·3	28·88	0·065	„
5	77·2	6th „	5th adm. 45 per cent.	333	23·0	80·14	0·043	0·065
6	82·7	„ „	5th notch	400	27·6	96·26	0·087	0·194

A counter was used to register the speed of the engine, and the vertical and horizontal motions were marked by pins applied for that purpose.

The speed at the sixth trial could not be accurately measured because the counter broke down, but the engine made at least 400 revolutions per minute.

The second trial of the engine was made with one carriage weighing 4·9 tons, and at all speeds up to 66 miles per hour, over all parts of the line, both in good repair and in bad repair, crossings, &c., it was found to be perfectly steady, no oscillation or plunging being discernable even at the greatest velocity.

In order to obtain accurate results of the influence of double cylinders and cranks, the "Rokitzan," one of the twelve express engines lately constructed for this line, all of which were of precisely similar dimensions and make, the Duplex being exactly similar, excepting the four cylinder arrangement, was lifted and slung in a similar manner to the Duplex. The driving wheels had the usual balance weights attached to them, equal to 0·8 of the masses that would be required to fully counteract the horizontal movements, and the table below gives the result of the trial:—

No. of Trials.	Steam Pressure.	Position of Regulator.	Position of Reversing Lever.	Revolutions per minute.	Piston Feet per minute.	Speed of Locomotive in miles per hour.	Disturbing Motion in inches.	
	lbs.						horiz.	vertic.
1	88·2	1st notch	1st notch adm. 65 per cent.	130	9·0	47·52	0·259	1·642
2	88·2	4th „	5th notch adm. 45 per cent.			31·29	0·259	0·388
3	88·2	„ „	6th notch adm. 40 per cent.			37·7	0·173	0·777

The lateral motion of this engine was so great during the first trial, that the revolutions, &c., could only be safely taken, and the observations made during the second trial. The vertical movements were regular, and, as far as could be judged, corresponded with the vertical motions of the balance weights, so much so that the upper and lower margins of the vertical motions of the engine corresponded with the highest and lowest position of the balance weights.

When tried on the road in a similar manner to the Duplex, no difference was observed in the working of the engine by those in charge up to 56 miles an hour, but above that speed it was found that unsteadiness commenced.

SUPERHEATING.

We are not at the present aware of any locomotive being arranged for this purpose in Great Britain, although engines so arranged have been in use for some time on the Continent. In the International Exhibition of 1862 there was one enormous, ungainly-looking locomotive, with its funnel laid on the back of the boiler, and the mouth of it opening just over the top of the fire-box, which was specially fitted with a superheating arrangement. In the horizontal part of the chimney is placed the superheater, which consists of a number of tubes, through which the heat from the fire-box passes, and around which the steam to be superheated circulates, taking up a portion of the heat that would otherwise escape into the atmosphere and be lost. This is a tank engine, has outside cylinders, and all wheels coupled, and is of a very heavy class, the lightest weighing some 45 tons. The boiler is of the ordinary tubular type, and there is a large amount of grate surface; but it is a question whether the long run which the products of combustion have to pass before escaping into the atmosphere, would not cause the steaming powers of this engine to be rather deficient. There were also drawings close by this engine of an arrangement for propelling with four cylinders, two being placed at each end, in those cases where great power is required, and it is desirable to distribute the weight by using several pair of wheels, which would not do so well when all were coupled. This plan is deserving of attention, as it seems capable of fulfilling the purpose intended. Engines of this description have been in use in France for some eighteen months or two years, with, it is said, very satisfactory results, the coal used being of a very inferior quality.

We do not think, however, that the design and arrangement of this engine will be copied in English locomotive practice, although there are many points worthy of notice, and which might be used with advantage.

LONDON, CHATHAM, AND DOVER, AND GREAT WESTERN COMPANIES.

PIMLICO STATION.

DESCRIPTION OF ROOF.

Plates 11, 12, 13, 14, and 15.

GENERAL DESCRIPTION.

This roof adjoins that of the London, Brighton, and South Coast Railway, which is illustrated in this volume by plates, Nos. 1 to 8 inclusive, and is known by the general designation as the Victoria Station, Pimlico. It is erected from a design furnished by Mr. Fowler, C.E., and was executed and erected under the superintendence of Mr. William Wilson, C.E., by the Horsley Company. It consists of two segmental arches of unequal spans, and of unequal lengths, as shown by the roof plan (plate 11), one is 455 feet in length, by 127 feet 4 inches in breadth, and the other is 385 feet in length by 129 feet in breadth. The difference in width was found necessary to avoid the disturbance of the then existing arrangements of the station. The height from the rails to the bottom of the gutter at the eaves at the intersection of the ribs is 36 feet, and from the rails to the underside of the bottom flange at the centre of the main ribs is 63 ft. 6 in. Each of these sheds is longitudinally divided into bays of 35 feet by the main ribs springing on the outer sides from the brickwork of the station buildings on the one side, and the outer wall on the other, and resting in the centre on ornamental cast-iron columns. These columns are bolted down to foundation plates, which are again bolted to a stone foundation, 2 feet below the level of the rails, and they serve as pipes to convey the water from the roof to the drains; they are each 38 feet and $\frac{5}{8}$ of an inch long. The heads of the columns are connected together in the line of the roof by cast iron elliptical girders, the spandrels of which are filled in with open scroll work of rich design. Each column supports a pair of main ribs, and the bay is again subdivided into three parts by two intermediate ribs, springing from the sides of the gutter. This gutter, which runs along the whole length of the roof, rests upon the top of the elliptical girder, and is provided with an outlet to each column. The outer gutters rest on the walls. The covering of each roof is supported by eight trussed and six trelliced purlins, which are bolted to the main ribs. On these purlins rest timber rafters, which carry the corrugated zinc covering. The top of each shed is ventilated by a louvre, which is 18 ft. 5 in. in width, running thoughout its whole length, and is lighted by means of the glass top of the louvre and by two sky-lights, one on each side, which also run the entire length of the shed.

COLUMNS.

Each column stands upon a bedplate, which is bolted with four 2″ jagged bolts, run with lead into the stone foundations; this bedplate forms a cup to receive the

water having a flanged mouthpiece cast in the side of it, to which is bolted the flange drain pipe. The base of the columns is octagonal, the shaft is circular, having a foliated base cast in one piece; the capital is cast plain, and the ornamental foliage is cast separate and fastened to it by screws. The top of each column is furnished with a flange, which is turned perfectly true, and the inside also bored true, to receive the end of the cast-iron gusset piece, the shoulders of which form the springing for the main ribs. The gusset-piece is elongated above the shoulder or foot 6 inches, forming a saddle to receive the hollow shoe of the main ribs. The centre of the gusset-piece is cast hollow, to correspond with the column, in the top of which are twelve slotted holes to receive the bolts for securing the heels of the springers of the main ribs. At right angles with the gusset-pieces chases are cast to receive the ends of the elliptical girders.

ELLIPTICAL GIRDER AND GUTTER.

Each of the elliptical girders is cast in two pieces, with a flanged joint in the centre, secured together by means of four $1\frac{1}{4}$-in. bolts, and adjusted by means of two wrought-iron folding keys, the joint being concealed by a cast-iron cover-plate, forming an ornamental pendant, which is fixed to the girder by $\frac{1}{2}$-inch screws. The haunches of the elliptical girders are fixed to the gusset-pieces of the columns by means of ten $\frac{7}{8}$-inch bolts and nuts. The gutters are cast in 11 ft. 8 in. lengths, and break joint over the columns, where they have socket-pieces, dropping into the hollow centres of the gusset-pieces; at the intermediate ribs, the ends have internal flanges, and are fastened together with six $\frac{7}{8}$-inch bolts and iron cement. The gutter is bolted to lugs cast on the top of the elliptical girder.

MAIN RIBS.

These ribs are segments of an arch of 78 feet radius, having tie-bars which form a catenary curve, with a rise of 8′ 6″ in. centre, and are attached to the rib at 15 points by radial rods; they are 4 feet deep, and are composed of top and bottom booms, divided into thirty-two compartments; the bays at the feet, which rest on the column for a height of 7 feet 6 inches above the springing, are curved to a radius of 17 feet $3\frac{1}{4}$ inches, and are filled in with boiler-plate, the upper part of which is single and $\frac{1}{2}''$ in thickness, the lower part, for a height of 2 feet 4 inches, forming the shoe which fits on the cast-iron saddle of the gusset-pieces, is double and of $\frac{3}{8}''$ plate. The feet, which rest on the walls, are filled in with single $\frac{1}{2}$-inch plate. The remaining portion of each rib is divided equally into thirty compartments by straining-bars, and the intervals crossed-latticed. The top and bottom booms are composed of double angle iron, each $5'' \times 3\frac{1}{2}'' \times \frac{7}{16}''$, spaced by washers $\frac{1}{2}$ inch thick, and rivetted together at about 12-inch pitch by $\frac{3}{4}$-inch rivets; the joints are secured with covering plates 2 feet long by $10\frac{1}{2}$ inches wide by $\frac{3}{4}$ of an inch thick and eight $\frac{3}{4}$ rivets, also by fletches between the angle irons 2 feet long by 3 inches wide and $\frac{1}{2}$ inch thick. The straining bars are composed of double T irons, each $4\frac{1}{2}'' \times 2\frac{1}{2}'' \times \frac{1}{2}''$ placed back to back transversely to the rib curved out at the extremities to admit of the flange or web of the booms and the lattice bars passing between them; the straining bars to which the lattice purlins are attached (see section at M, Plate 13) are alike top and bottom, and are turned up at the ends and rivetted to the horizontal flanges of the upper and lower booms by $\frac{3}{4}''$ rivets. In the straining bars, to which the trussed purlins are attached, the web of the T iron is cut away at the lower extremities, and the flange is rivetted to the web of the lower boom, as shown by section N, plate 13. The lattice bars are 3″ by $\frac{1}{4}$ of an inch, passed between the double T iron of the straining bars, and are rivetted between to the webs of the booms.

The tie rods or chains consist of three flat bars, each $4'' \times \frac{1}{2}''$, having the joints at the junctions with the radial rods. They are connected to the feet of the main ribs by two flat bars, each $7'' \times \frac{9}{16}''$, which are rivetted to the boiler-plate, which falls in the lower compartment of each rib.

The chains and connecting bars forming the junctions are slotted and united with gibs and folding wedges for adjustment. The radial bars are $1\frac{1}{8}''$ round iron, and are connected with the lower boom of the main ribs by shackles.

The ends of these shackles are screwed with a left-hand thread, and the end of the rod with a right-hand one, and adjustment is thus provided by means of an elongated nut tapped with a reverse thread; a lateral adjustment is likewise provided by a hinged joint of each radial rod. (See sheet 15.)

The foot of each main rib, which rests on the outer walls, is supported on rollers fixed in a frame, by which contraction and expansion is provided for. (See bed-plates, plate 14.) The outside of the cast-iron brackets, which are bolted on to the feet of the ribs, work in chases left in the brickwork, thus holding the rib in its position without interfering with the adjustment.

INTERMEDIATE RIBS.

Each of these ribs consists of a single bar of T iron, $3\frac{1}{4}'' \times 3\frac{1}{2}'' \times \frac{9}{16}''$, curved to the same radius as the outer boom of the main rib; the foot of each of these ribs is bolted to the side of the cast-iron gutter, and rests upon a lug cast on the same, the gutter at this point being strengthened by a straining piece passing from side to side.

LATTICE PURLINS.

The principal purlins are the same depth as the main ribs, and are each divided into three spaces by straining bars and latticed intervals; the top and bottom booms or flanges are formed of double angle iron, 4″ × 2½″ × ⅜, spaced by washers, and rivetted together by ¾″ rivets at 18 inch pitch; the straining pieces are formed of double T iron, 4″ × 4″ × ⅜″, joggled at the extreme ends to span the double angle iron of the booms and the lattice-bars, all of which are fixed together by the same rivet. (See fig. plate 15.) The lattice bars are single, each 3½″×⅜″. These purlins are attached at each end, both at the top and bottom, to the booms of the main ribs by means of ⅞″ rivets; passing through the ends of the straining bars of the main ribs, the purlin ends are again connected to each other and the main rib by ⅞″ covering plates and twelve rivets. (See plans and sections at M, plate 13.)

TRUSSED PURLINS.

These purlins are 2 feet deep, and are composed of double angle iron, each 4″×2½″×⅜″ of an inch, forming the top boom or flange, spaced with washers and rivetted together by ¾″ rivets at 18″ pitch; they are divided into three equal portions by queen-posts struts of two flat bars, each 3″×⅜″, which are rivetted between the L irons of the top boom and joggled at the lower end to receive the joint of the tension rod, which is secured by a ¾″ bolt and nut over each of these struts. One of the intermediate ribs passes and is rivetted to it, and the strut is stiffened laterally by means of T iron-curved braces, which are rivetted at one end to the flanges of the intermediate rib and at the other to the struts; the tension rod is of 1⅜″ round iron, with a joint at each strut, and is drawn flat at each end, slotted and housed between the L irons, to which it is secured by folding wedges for adjustment. (See section of purlins, plate 15.)

WIND TIES.

The six bays formed by the main ribs at each end are cross braced by wind ties of 1½″ round iron; these wind ties are bolted through the tie rods or chains, and the ½″ plate at the foot of every alternate main rib, and are bolted at the other end to the lower flange of the intervening main rib, at a point intermediate between the springing and the louvre, and a similar bar is continued to the underside of the next main rib, immediately below the side of the louvre; these braces thus cross one another at the centre of the intervening main rib, where the ends of the four rods are secured by a covering plate, and bolts, and nuts. Adjustment is provided by means of a right and left-handed screw at the centre of each rod (See Roof Plan, plate 11 and also plate 14).

LOUVRES.

The louvres are continued throughout the whole length of each shed, and span the four centre compartments of the main ribs, the standards being fixed on the top of the main boom immediately over the head of the straining pieces, and are 3 feet 9 inches in height; the roof which covers this space is 18 feet 5 inches span, and is laid to a pitch of 1 in 2½, and is composed of two king-post trusses meeting at the ridge, where they are secured by a cast-iron king-head, and tied together at the feet of the king-posts by means of a ¾ inch round rod; the tie rods of the king-post trusses are ⅞″ and ⅝″ round iron respectively. The rafters of this roof, which are attached to the king-posts, are of T iron 2½″ × 2½″ × ⅜″, and overhang the uprights 3 feet 9 inches on either side, and this is supported by means of cast-iron brackets. The ridge piece and purlins are of fir, traversing the whole length of the roof, and are lined on each side with a ⅜″ wrought-iron plate; these plates and timbers are secured to the rafters by double brackets formed of angle iron. The timbers carry the metal sash bars, which are secured to them by jagged brob nails; the eaves purlins are held down to the rafters by ½ inch coach screws, and the others are bolted through the brackets by ⅝″ bolts and nuts (see Sheet 15).

SKYLIGHTS.

The metal sash bars of the skylights rest upon timber bearings, which are brought up to the required level, and carried by means of cast-iron brackets attached to the purlins; the lower end of the skylight is raised by a perforated cast-iron plate, left open for ventilation; the ends are enclosed with a framing of wrought-iron, wood, and glass.

CONDITIONS.

The following are some of the conditions under which the contract was taken, viz.:—

The construction, erection, completion, and painting of the cast and wrought-iron work, builder's work, glazier's work, and all other things necessary for the entire completion of the roof.

Castings.—To be clean and sound, entirely free from sand, air-holes, or other flaws; to be run from the cupola without any admixture of cinder. The metal to be composed of two-thirds of No. 2 hot-blast grey pig, mixed with one-third of No. 3 cold-blast; small or ornamental castings, the object of which may be appearance rather than strength, to be run from metal of a quality sufficiently fine and soft to obtain clean and sharp arrisses and a smooth surface; all joints to be provided with chipping pieces, and accurately fitted together; bolt-holes to be rimed to the exact diameter of the bolts. In columns, or other hollow castings, care must be taken to preserve the uniform thickness

of metal. All castings to be scraped, cleaned, and painted with best red-lead and oil, before leaving the works. Plugging not to be allowed.

Wrought Iron.—All plates to be of uniform thickness, and of the sizes shown on the drawings, and curved, flattened, or bent to the required form, and to hold the full length. All nuts to be equal to the diameter of the bolt, and the heads three-quarters of such diameter. Washers to be 2½ diameters of the bolts; and when connecting timber, to be square, and equal in area to at least twenty times the sectional area of the bolts. All bolts to project one diameter beyond the nut when tightened up. All plates to be equal in quality to the best Staffordshire boiler-plates, free from blisters, scales, and other defects. Angle bars and T iron to be equal to B B merchant bar, and of such quality as will not crack or split with any bending, punching, or rivetting. Bolts, nuts, rivets, straps, and tie-bars to be wrought from best S C crown iron. Plates, bars, rods, &c., to be placed in the work so that the fibre of the iron shall run in the direction of the greatest strain. Screwed ends to rods and bolts to be clearly cut, and tightly fit the nuts; and where subject to a tensile strain, the ends, before screwing, to be swelled out as much as may be necessary to maintain the full sectional area of the iron at the bottom of the thread.

Rivet-holes in the first instance to be punched smaller than the rivets they are to receive, and afterwards, when the plates are put together, to be rimed out to the exact size, precaution being adopted to secure the precise correspondence of the holes throughout any number of the plates or bars, and the exact fitting of the rivets within such holes. Rivets to be rose-headed, and set up entirely with the hammer, and without the use of any set or swage.

Tests.—Any portion of the iron used shall be submitted to such tests of its strength as the engineer may think fit to apply. The best quality, for bolts, to sustain without injury 20 tons per inch of sectional area; the second quality, for bars and angle iron, a weight of 18 tons per inch of sectional area; and the third quality, for plates, a weight of 16 tons per square inch. Corrugated and sheet iron to be of the best charcoal plate. Iron cement joints shall, when ordered, be made perfectly water-tight.

Glazier's Work.—Skylights and roof sashes to be glazed with sheet glass, weighing 21 oz. the foot super, and to be well bedded and front puttied.

Painting.—All ironwork to receive over the whole accessible surface one coat of best red-lead and oil paint before leaving the works; and after erection, all iron and woodwork to receive three coats of best oil colour, composed of the best white and red-lead, mixed with the best boiled oil and turps.

Zinc Covering.—The zinc for the roofs to be Devaux's roofing zinc (obtained solely from Messrs. Devaux and Co., each sheet being stamped with their name). The sheets to reach from purlin to purlin, and to be No. 15 gauge; the laps, flashings, and welts to be of No. 14; the whole to be laid without confinement by nails or solder, and according to the method shown on the drawing (plate 15), so arranged that, while the roof is perfectly water-tight, the zinc shall be free for expansion and contraction.

Timber.—The woodwork to be of best Memel or Riga red pine; fir mouldings; panels and other work of similar character, Quebec yellow pine.

The total cost of these roofs was £24,250, or about £27 13*s.* 4*d.* per square of 100 feet superficial, area covered.

CREMORNE MUSIC HALL.

DESCRIPTION OF ROOF.

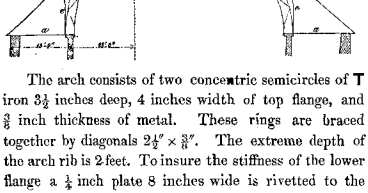
Plate No. 16.

In the restoration and re-arrangement of the Cremorne Gardens in 1862, it was determined to rebuild the Music Hall and Theatre, and a plan was prepared for this purpose by Thomas Allum, Esq., architect.

The body of the hall, independent of the stage, is 136 feet long, 69 feet wide, width of galleries on either side 12 feet, leaving a centre width of 45 feet. It was designed to cover this centre portion by a circular roof, having the panels filled in with ornamental work, to prevent any part of which being hid or intersected, ties must necessarily be dispensed with. To obtain this object the circular form was adopted, and supposing that a roof could be constructed which should be perfectly rigid and evenly weighted, this condition would be fulfilled; but the most perfectly constructed roof will be subject to inequality of pressure, and in the present case, independently of the strains likely to be produced by an accumulation of snow or pressure of wind, it would probably be necessary to weight it, though slightly, in arranging the internal fittings. To meet these requirements Mr. W. Humber, C.E., who furnished the design of the roof, took advantage of the

leverage which the projection of the galleries beyond the springing of the arch spanning the centre afforded, to tie its abutting parts back to the outer walls of the erection, thus making each segment of the arch self-supporting, until the weight at the extremity should overcome the moment of gravity of the side galleries, with their solid brick outer walls, a contingency not likely to arise even if they had stood alone, but which becomes a very remote probability when the pressures of these two opposing forces are counterbalanced by the crown of the arch. It was originally intended to continue the corrugated iron covering of the crown along the tension bars, which would have been strengthened by trussed purlins, but the serviceable condition of the roofs of the old structure suggested the expediency, from motives of economy, of refixing them over the galleries, and making the compression bars of the circular roof act as their ties.

FIG. 1.



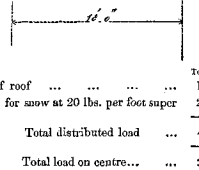
The arch consists of two concentric semicircles of **T** iron $3\frac{1}{2}$ inches deep, 4 inches width of top flange, and $\frac{3}{8}$ inch thickness of metal. These rings are braced together by diagonals $2\frac{1}{2}'' \times \frac{3}{8}''$. The extreme depth of the arch rib is 2 feet. To insure the stiffness of the lower flange a $\frac{1}{2}$ inch plate 8 inches wide is rivetted to the under side, and carried upwards to a height of 18 feet from the springing. On either side, the springing plate (a) of the arch is elongated to the outer walls, upon which it rests, and forms the tie beam of the roof principal over the galleries.

To the extremity of this tie beam the tension rod (c) is attached, and forms a tangent to the arch at (b), where it is rivetted to the outer member, leaving a crown piece of 18 feet between the supported segments. This external supporting tie is formed of **T** iron of the same sectional area as the top and bottom members of the arch. In order to meet any tendency to buckling between the point (b) and the springing, a vertical tie (e) is inserted $2\frac{1}{2}'' \times \frac{3}{8}''$, and from its point of junction with the main tie a short strut of $1'' \times 4''$ bar rests upon the arch at (d), thereby forming a complete truss. Each principal is supported on columns in double tiers; the lower ones carrying the floors of the galleries on iron girders 12 inches deep. These girders pass through the outer walls, and through them are bolted the ends of $1\frac{1}{4}$ inch rods, by which the outer end of the roof tie of the galleries and the main external tie of the principals are secured to the external walls.

The result of this arrangement is, that a very strong roof has been constructed with considerable economy of material, capable of any amount of ornamentation, the view along the nave being quite unobstructed.

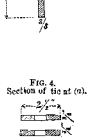
In treating of the strains to which this principal may be subjected, it is evident that the side portions of each principal, between the springing and the point of contra-flexture, may be treated as a cantilever or rather crane counter balanced by the weight of the galleries and outer walls, and the intervening 18 feet of the crown, as a simple slightly curved triangular girder. The distance between the principal is 14 feet 6 inches. The calculation assumed for the construction of the roof has proved to be exceedingly near the truth, and was as follows:—

FIG. 2.



		Ton.	cwt.	′	″
Weight of roof		1	15	0	0
Provision for snow at 20 lbs. per foot super		2	5	0	0
Total distributed load ...		4	0	0	0
Total load on centre... ...		2	0	0	0

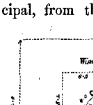
FIG. 3.
Section of rib at (b).



		Ton.	cwt.	′	″
Taking W = centre load ...		2	0	0	0
„ S = span in feet ...	18	0	0	0	
„ a = area of top or bottom flange 2·5 inches.					
„ d = depth of girder in feet ... 2·0 „					

Then the strain on the centre (b), Fig. 2, by formula $\frac{WS}{4ad}$, would be $= \frac{2 \times 18}{4 \times 2{\cdot}5 \times 2} = 1{\cdot}8$ tons per inch.

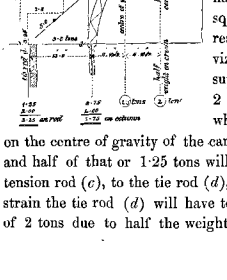
FIG. 4.
Section of tie at (a).



Strain on tie at (a) by measurement	3·8 tons.
Area of tie (a) with holes deducted	1·3 „
Therefore the tension strain per inch of section will be	3·0 „

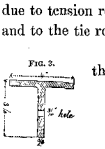
The weight of roof upon and inclusive of each principal, from the springing to the points of contrary flexture, was taken as 1 ton 10 cwt., and the weight of snow which could rest upon it at half the quantity per square foot which could rest upon the crown, viz., 10 lbs. per foot super, making together 2 tons 10 cwt., the whole of this will act on the centre of gravity of the cantilever or jib crane, and half of that or 1·25 tons will be transferred to the tension rod (c), to the tie rod (d), independently of this strain the tie rod (d) will have to bear a tensil strain of 2 tons due to half the weight of the crown piece,

FIG. 5.



being together 3·25 tons, the weight of roof. By the resolution of forces this weight will be equal to a strain of 5 tons on the tension rod (c) and 3·8 tons on the tie rod (a), besides these strains there are others due to the pressure of the wind, which may be taken at 4 lbs. to the foot super upon an area represented by the height of the arch, and the width pertaining to each bay, viz., 14'·6" × 24 feet × 40 lbs. = 6·2 tons. This strain is also transferred by the resolution of forces to the tension rod and tie rods in the following amounts; due to tension rod (c), 8 tons, to the tie rod (a) 6.2 tons, and to the tie rod (d) 5·4 tons.

FIG. 2.



The several amounts may be stated thus on tension rod (c):—

Due to weight of roof	...	5 tons.
Ditto action of wind	...	8
		13

Section of rod, exclusive of holes, 2·5 inches = 5·2 tons per inch on tie rod (a):—

Due to weight of roof	...	3·8 tons
Ditto action of wind	...	6·2 „
		10·0 „

Section of rod 2·5 inches = 4 tons per inch of compression on tie rod (d):—

Due to weight of roof	... ...	3·25 tons.
Ditto to action of wind	... ...	5·4 „
		8·65

Section of tie rod 1¼ inches = 8·65 tons per square inch.

These parts of the roof have been principally treated of, as they are subject to the greatest strains.

It is hardly necessary to attend to the strength of the columns to support the dead weight, as it was necessary for artistic reasons to design a column which was larger than the mere weight of the structure required.

The weights of roof are as follows:—

	Tons.	cwt.	qr.	lb.
9 ribs or principals, each 1 ton 11 cwt. 1 qr. 27 lbs., or	14	3	1	19
140 purlins 14 feet 6 inches apart	12	18	3	13
9 ties for purlins	1	0	3	0
2 wind ties	1	6	0	24
18 1¼ tie rods	0	8	0	4
Bolts and nuts	0	2	7	0
Corrugated iron, No. 18 gauge	9	14	2	3
C.I. brackets and corner plates	1	0	3	20

Cost £750, or £12 5s. per square of 100 feet superficial.

CONSTRUCTION OF HARBOURS, PORTS, AND BREAKWATERS.

HISTORICAL.

THIS treatise on the formation of breakwaters is not intended to describe any new and untried method of erecting marine structures of this character; the observations to be made will have reference only to the early examples, and the modern progress of that division of engineering art which relates to the creation of deep-water barriers capable of resisting the force of heavy waves, generated by powerful storms, and of giving refuge to ships during the continuance of tempestuous weather.

From the earliest historical times efforts have been made to afford shelter to ships and vessels in roadsteads, harbours, and sea estuaries. The people inhabiting the coasts of Egypt,* Syria, Greece, Africa, Septentrionalis, the ancient Italia (Latium), and Venetia (Venice), situated on the borders of the Mediterranean, were from the earliest period dependant on maritime intercourse, and the development of commerce. Hence the necessity of maintaining floating defences caused attention to be paid to the construction of submerged works of great difficulty, and of considerable extent and durability.

The works above alluded to, if measured by the dimensions of modern structures, would appear very small; but if the period of their erection, the want of experience of that age, the isolation of the separate communities, and the constant liability to hostile attacks from contiguous nations, be taken into consideration, we are compelled to admit that the works must have been of an important character, and constructed of hydraulic materials of an enduring, ponderous, and massive nature. But faint traces of these works now remain, to point out the locality of their usefulness, and the unyielding quality of the material used in their composition. On the coast of Egypt, east of and near to Iscander (Alexandria), may be seen the remains of sea-terraces, formed of gravel concrete of great adhesion, cemented by hydraulic lime, derived from the magnesian limestone of the Mocatam range of hills. The mixture seems to have been well studied, the composition being about two-thirds gravel and one-third lime. The gravel is chiefly

* The principal local positions relating to the ancient constructions of maritime works existed in the antique sites of Soida (Sidon), Sûr (Tyre), Akka (Ptolemais), Yafa (Joppa), Suyda (Zydon), Alexandria (Iscandar), Canopis (Carthage), Carthidon (Carthagena), Venetia, Veneti or Heneti (Venice), Ostia† (a Roman colony at the mouth of the Tiber), and other marine positions on those ancient and once celebrated territories.

† Ostia condigerat qua se *Tiberinus in altum*. Dividit et campo liberiore natat.—OVID.

derived from the debris of limestone sea-drift, and appears to have been used very clean, and laid down in a continuous mass; but the oceanic action of the waves has undermined the foundations on which the concrete was laid; it is, in consequence, now in a broken state, but the detached masses are sufficiently large to oppose an effectual barrier to the further encroachments of the sea in that locality. The work was effected some time between the conquest of Egypt by Alexander, and its subsequent conquest by Julius Cæsar; but the latter period is likely to be most correct, because the level of this coast has geologically been altered slightly by declining into the sea. When the terrace was first constructed, it was undoubtedly placed above the highest movement of the wave acting on the shore; it now forms the perimeter of the tide, which is only four feet of altitude at the highest point; consequently, the neighbouring ground has been raised, at different periods, by materials derived from the ancient accumulations of the city of Alexandria, in which debris may be seen a succession of roads, one of them being composed of Cyclopian stones, formed into a pavement, and obtained from the greenstone rocks of Upper Egypt. The stone is beautifully shaped and fitted, and is nearest to the marine terrace we have before spoken of. Now, as the road leads from Alexandria to the camp of Cæsar, a short distance eastward from the visible part of the terrace; it may be inferred that the maritime work was effected as early as the time of the Ptolemies, and that the road was constructed during the period when the first Cæsar exercised dominion over this part of the world. At the site of ancient Canopis, Kahi-noul (the ancient Brighton of Alexandria) may yet be seen the marine submerged works used for forming deep-water barriers to the sea, and constructed for the purpose of landing cargoes and passengers from large vessels arriving from, and departing for, distant localities, and promoting a continued intercourse with the neighbouring city of Alexandria. The barriers or sea-terraces of Canopis were constructed from materials and statues of colossal size, derived from Egyptian temples of a much earlier date, and which still exhibit the indications of the chisel as fresh as when extracted from the quarry.

Between the old port and the great harbour, or new port of Alexandria, there was constructed the island of Pharos, connecting the city and the island by a deep-water mole, now of great width, anciently called the Heptastadium. The value of this work and the necessity of constantly maintaining inter-communication with the island, has caused its continued maintenance up to the present age, whilst the result of all other Eastern movements for creating or maintaining harbours, deep sea moles, and landing places have faded from sight by neglect or the lapse of time.

The great mole of Sûr (Tyre), which connected the mainland with the city, afforded a means of communication between the contiguous coast and the thickly inhabited town. The boundary of the city was carried out into water of the sea; this most probably arose from the necessity of creating new areas, for the constantly increasing population living by manufacture and commerce on a most limited space. The ancient city of Venice, like old Amsterdam, was planted in sea water; and, the foundations of their heaviest buildings, extensive arsenals and depôts were placed among lagoons and deep-silted morasses; consequently, artificial foundation of great strength, capable of unyielding resistance, and sufficiently deep to reach a solid bottom, had in past times, and even now, requires to be created before the imposition of the great weight of any large structure. Along the coast of Asia Minor and at Constantinople, when Athene (Athens) sought to strengthen her naval and military position by forming seaports and harbour towns having deep-water inlets connected with the Acropolis and Piræus, by high walls of great extent, and brought into usefulness chiefly under the administration of Themistocles and Pericles, the erections were of necessity massive, and extended into deep water. The stone used for the structures was large, as there was the advantage of contiguity of Mount Pentelicus, which yielded sound blocks of great dimensions and unequalled beauty; but the slow action of time has nearly obliterated all traces of these noble constructions. Few of the marine works which were once located in the passage of the Dardanelles and near Constantinople remain, whilst the maritime Phœnician cities situated on the coast of Syria and bounded on the east by Cœlo-Syria, extend on the west to the River Elentherus, and on the north to Mount Carmel, and about twelve miles along the south shore, the spurs of Mount Lebanon are thrown out into the sea, forming high bluffs, on the elevations of which were once situated some of the greatest and most important, rich, and powerful cities of the ancient world. The inhabitants of these were regarded as the inventors of letters, the first teachers of astronomy, the arts and sciences, and having commercial relations with all parts of the then known universe, it may be imagined that the genius of a people so learned, enterprising, and capable would be equal to deal with submerged works of a character then regarded as of the greatest magnitude.

The locality of the maritime city of Carthage was until recently unknown. The inner ports and the outer harbour are now entirely obliterated by the deposit of sea-sand, which travels along the coast. The seaport of Ostia, capable of containing all the fleets of the Roman Empire, was created by artificial means. The moles, wharfs, and retaining walls were substantially constructed of concrete masonry of

vast dimensions; but Ostia, once the seaport of the Cæsars, only fourteen miles from Rome, is now entirely choked up, whilst the neighbouring country has returned to its primeval state of waste; the wild hog, the bandit, and the sickly remnant of an expiring race, being its last inhabitants.

It may be concluded that in those early periods, the same motive, although in a less degree, existed, as that which now gives influence to maritime nations, in directing attention to the improvements of harbours, and to increased facilities for entering natural ports; but the creation of extended wave barriers for giving safe anchorage to ships driven from the open sea by the force of storms, belongs to the efforts of modern science.

The examination of the ancient compositions which chiefly form the old marine works, deserves much consideration. The use of concrete dates from very remote times, and almost beyond the records of history. The Greeks, Romans, Scythians, Hindoos, and Chinese, and the ancient architects of the mediæval period, availed themselves of this material, both for building and submerged works. The extensive use of plastic and granular materials, in the construction of concrete, by all the countries named, caused lime to set with great hardness, especially under water. The European and African countries directed attention chiefly to the use of puzzolana, lime, clean sand, small gravel, and rubble rock, in due proportions, so as to use the smallest quantity of lime, and filling the interstices by gradations of one size after another, by which means no voids were left in the mass. In Syria, dependence was chiefly placed on lime derived from Dolomite, or magnesian rock, mixed with materials containing sugar. The same substances, in a great degree, form the chunam of Ceylon, India, and China, but its goodness and durability is either dependent on lime and puzzolana, or the magnesian rock, the saccharine matter is mixed in a plastic state either under edge-runners or pounded by hand-pestles with great force. It is believed that the use of edge-runners was known at a very early period.

We have seen ancient works at Aden of great magnitude for storing water, which were erected by the Phœnecians. In Aden it only rains but once in three or four years, hence the indispensable necessity of constructing reservoirs which are calculated to astonish a Modern Engineer by their vast dimensions, superior workmanship, and the skilful design, by which they were first carried out; some of these works have only recently been discovered, and are so interesting, that they will receive notice in subsequent pages.

GREAT NORTHERN RAILWAY.

PARISH ROAD BRIDGE, KNEBWORTH.

DESCRIPTION OF BRIDGE.

Plate 17.

This bridge was erected in the year 1849, from drawings furnished by Mr. Joseph Cubitt, C.E., and carries the parish road over a chalk cutting 53 ft. in depth. The arch is a segment of a circle of 66 ft. radius, and the chord of the segment is 96 ft., with a versed sine of 20 ft. 9 in. The soffit, or arch proper, of the bridge is only two-and-a-half bricks, or five rings, uniform thickness, and springs from a stone skewback on the face of the abutment. This arch is strengthened by five ribs springing from a skewback of York stone, 6 in. in thickness, passing along the extreme width, set to the proper angle, at a point further back on the lowest footing of the abutment, and they are carried up, as shown, and comprise seven extra rings, making twelve rings at the crown of the arch, and nineteen extra rings, making twenty-four rings at the haunches. These extra ribs are tied together by means of three tiers or courses of York stone bond, each 2 ft. wide by 6 in. in thickness, running the whole width of the bridge, as shown, in cross-section. Upon these back ribs are built spandrel walls, which carry the flag-stone, 6 in. thick, forming the foundation of the roadway. As these ribs carry the weight of the roadway, the arch is as strong as if of the greater thickness all over. The abutments and wing walls are hollow, the front wall of the former being only 2 ft. thick between the wings, and being strengthened by the heel of the back ribs. The abutments are 14 ft. from front to back, and 4 ft. thick under the arch, and 5 ft. 6 in. under the back rib. The nature of the soil, being firm chalk, admitted of these abutments being very slight, and it was also taken advantage of by the contractor to save expense in constructing the centering; the earthwork was only removed on the site of the bridge to the form shown by the upper dotted lines, and on this core the centres were erected; they consisted of half baulks, 12″ × 6′, laid transversely to the line of the bridge on which the slack blocks rested, and on these the centres were carried, the entire space was divided into three portions or segments, each having its own tie-beam, struts, and blocks, and over the whole the arch rib was formed of six 1-inch thicknesses of laminated timber. The arch and back ribs were built in Roman cement, the remainder in mortar. The quantities were as follows, viz.:—

322	cubic yards of excavation in foundations.	
877	do.	of brickwork in mortar.
513	do.	of brickwork in cement.
2,370	cubic feet stone in skewbacks, string-course and coping.	
259	superficial feet, 6″ York, in bond stones.	
2,200	do.	6″ York, in covering.
11	lineal feet of 6″ cast-iron water-pipe.	

DUTCH RHENISH RAILWAY.

AMSTERDAM STATION.

DESCRIPTION OF ROOF.

Plates 18 and 19.

THIS roof at the Terminal Station at Amsterdam was constructed from the designs of Mr. Euschedé, the Engineer to the Dutch Rhenish Railway Company, by Messrs. Ordish and Le Feuvre, the general arrangement and details of the works being shown by the plates.

The structure comprises a main roof for arrival and departure, shed and annexes for carriages and cabs, and goods office. The main roof is supported by twenty-six cast-iron columns which are fixed at a distance of 25 ft. from centre to centre longitudinally, and 120 ft. transversely, giving a covered area of about 300 ft. long by 120 ft. wide.

FOUNDATIONS.

The foundations for the columns are timber piles, on which are built brickwork piers, surmounted by stone blocks on which the columns are fixed. No. 4 cast-iron washer plates, 16 in. diameter, and four holding down bolts $1\frac{1}{8}$ in. diameter, and 5′ 6″ long, with enlarged screwed ends, are built in each pier, by which the bases of the columns are securely bolted down. This arrangement was necessitated on account of the roof being supported entirely on columns, and erected in a very exposed situation.

COLUMNS AND GUTTERS.

The shaft of the column is octagonal, the lower part square, with separate moulded hemispherical bases covering the circular base of the column; the upper part of the column is square, with a moulded cap and hollow corbels for supporting the ends of the gutters and carrying the water therefrom into the columns. The gutters are of cast-iron in one length between each pair of columns, and act as girders for supporting the roof covering.

PRINCIPALS.

The principals may be termed bow-string trusses, the arch or main compression member being of cast-iron; the tie-bars and diagonals being of wrought-iron. They are 120 ft. span from centre to centre of shoes, at springing, the rise of the cast-iron arch is 40 ft., and the rise of the tie-bars 17 ft., measured from springing-line, giving a depth of truss of 13 ft. in the centre. The word arch, is used in describing the compression member of the principals, but it is, in fact, polygonal, being composed of straight lengths of cast-iron tubes 8″ diameter, and angular connecting pieces; the abutting ends of the tubes and connecting pieces are turned, and are connected together at each joint by No. 4 bolts, $1\frac{1}{8}$″ diameter. The thickness of the tubes at springing is $\frac{11}{16}$ths in., diminishing to $\frac{9}{16}$ths at the centre. The tie-bars consist of two flat bars, each 4″ by $\frac{7}{8}$ths, with enlarged ends, rolled by Messrs. Howard and Ravenhill, the holes for the connecting-pins and bolts being bored, and the whole of the links proved with a strain of 12 tons per sectional inch without any permanent set. The diagonals each consist of two flat bars 6″ × $\frac{5}{16}$″, with an angle iron rivetted to each bar and connected together by wrought-iron plates. The pins and bolts for connecting the diagonals, cast-iron arch and tie-bars, are 3 in. diameter, accurately turned, and all holes through which they pass are bored to fit.

PURLINS.

The purlins are of cast-iron, each in three lengths, and are fixed to cast-iron standards which are bolted on the top of the cast-iron arch; they are of an average thickness of $\frac{3}{8}$ in., and are glazed with sheet glass 21 oz. to the superficial foot.

WIND TIES.

The wind-ties are of wrought-iron of an available section of 4″ × $\frac{3}{8}$″, the connections and adjustments are by means of gibs and keys.

VENTILATION.

Ventilation is provided at the top of the roof by means of cast-iron open-work ridge purlins, provided with a cover of corrugated iron for keeping out rain.

COVERING.

The roof is covered with corrugated iron, No. 16 gauge; the pitch of the flutes being 10 in. and the depth $2\frac{1}{2}$ in.; the sheets were dipped in boiling oil previous to erection, and were afterwards covered with two coats of oil paint.

COST.

The cost of this roof, erected and painted complete, including columns and holding-down bolts, but exclusive of foundations, was £15 7*s.* per square of 100 superficial feet of area covered.

STATISTICS OF RAILWAYS.

I.—EUROPE.

THERE is a great absence of accessible data of an official character, in any collected form, respecting the railways open or forming in various countries, the cost of construction, working expenses, &c. We feel, therefore, that we shall be doing a service to the profession in collecting, from reliable sources, all the returns obtainable, and giving these in a condensed form, as from these figures important deductions may be drawn. We commence with the European railways. The official returns, in some cases, are not accessible yet for the last two or three years.

FRANCE.

The following table shows the extent of lines open in France on the 1st of January, 1861, with the average receipts, &c., in 1860:—

NAME OF RAILWAY.	Kilometres Open.	Total Receipts. Frs.	Average per Kilometre. Frs.
Nord	997	60,639,762	61,940
Est	1,680	63,723,631	37,999
Ardennes	164	3,659,976	22,317
Ouest	1,212	50,900,000	42,206
Orleans	1,934	71,083,707	38,299
Paris—Mediterranee ...	1,937	120,616,753	63,166
Lyon à Geneve	237	6,891,113	29,076
Midi	895	24,266,264	27,174
Dauphine	129	2,740,269	21,242
Ceinture	17	1,715,542	100,914
Besseges à Alais	32	1,092,933	34,154
Anzin à Somain	19	388,869	20,467
Carmaux à Albi	15	189,060	12,604
Graissessac à Beziers ...	51	305,846	5,997
TOTAL	9,319	408,213,725	44,492

Between December, 1857, and December, 1860, 1,616 kilometres of new lines have been opened.

The kilometre is 4 furlongs 212 yards; but taking it, in round numbers, at half a mile, this gives the total length of lines open at 4,660 miles, and the average receipts per mile £3,558. The cost of construction we have not the details of.

SWITZERLAND.

The position of the railway lines in Switzerland in the close of 1860 was:—1,050 English miles of lines conceded, of which 660 were open, 132 in course of construction, and 255 miles not commenced.

BELGIUM.

Railway Returns up to 31st December, 1859.

Railways completed by the State:—

	Length. metres.	Cost. frs.
NORTH.		
Brussels to Malines	20,992	3,664,544
Malines to Antwerp	26,320	4,312,794
Branch Line of Lierre	6,175	381,864
WEST.		
Malines to Termonde	26,254	3,432,450
Termonde to Ghent	31,888	5,291,589
Ghent to Bruges	44,558	5,981,938
Bruges to Ostend	24,672	3,823,003
Branch to Lille and Tourney.		
Ghent to Deynze-Peteghem, Deynze-Peteghem to Courtrai	43,660	5,246,474
Courtrai to the French Frontier	15,062	3,356,555
Mouscron to Tournay	19,135	3,127,020
EAST.		
Malines to Louvain	23,583	4,390,439
Louvain to Tirlemont	19,071	6,075,632
Tirlemont to Waremme	27,024	5,039,595
Waremme to Ans	18,996	3,484,933
Ans to Mense,—Pont du Val-Benoit ...	6,610	7,001,550
Mense to the Prussian Frontier	39,580	23,675,756
Landen to Saint Trond	10,220	1,228,805
SOUTH.		
Brussels to Tubise	19,510	5,346,822
Tubise to Soignies	17,083	4,933,911
Soignies to Mons	24,533	5,303,661
Mons to the French Frontier	19,545	4,742,273
Branch Line to Brussels	2,782	1,222,178
Braine-le-Comte to Charleroy	41,600	10,390,436
Charleroy to Namur	38,181	7,875,918
TOTAL	567,024	129,850,139

The cost of constructing these lines was £5,193,205, besides about two-and-a-half millions sterling more for buildings and other expenses.

Lines formed by Public Companies:—

	Length. metres.	Cost. frs.
Lierre to Turnhout	37,373	4,300,000
East Belgian	96,065	20,894,775
Manage to Wavre	41,091	9,587,500
Western Flanders	120,988	15,023,294
Lichtervelde to Furnes	33,847	5,011,269
Entre Sambre and Meuse	105,241	27,363,187
Namur to Liege, and Charleroy to Erquelinnes	99,944	48,804,155
Pepinster to Spa	12,119	2,777,361
Hainault and Flanders	120,972	10,972,200
Antwerp to Rotterdam	119,296	14,927,720
Antwerp to Ghent	49,690	4,901,204
Dendre and Waes, and Brussels towards Ghent	107,119	22,000,000
Tourney to Jurbise, and Landen to Hasselt	75,018	13,740,205
Landen to Aix-la-Chapelle	93,460	20,796,580
Carrieres de Quenaest	7,500	303,855
Upper and Lower Flenu	60,760	4,546,273
Mons to Hautmont and St. Ghislain ...	52,461	17,254,013
Chimay	30,426	2,999,352
Centre	35,727	10,988,483
Grand Luxembourg and Ourthe Canal ...	207,112	66,614,353
TOTAL	1,506,209	323,805,772

The following is a summary of the preceding extracts respecting the Belgian Railways:—

State Railways.	Miles.	Cost.
North	33 ...	£354,369
West	128 ...	1,210,361
East	90 ...	2,035,868
South	101 ...	1,592,607
By Public Companies	936 ...	12,952,231

Total cost, including buildings and other expenses for the 1,288 miles, £20,583,548.

The total receipts on the State Railways in Belgium in 1858 were:—

	Francs.
North Lines	5,922,843
West „	4,599,209
East „	3,678,194
South „	7,920,764
	22,081,010
By Mixed and International Service ...	5,610,841
	27,691,851 frs., or £1,107,674

The estimated amount of the working expenses of the State Railways in Belgium in the years 1858–59, averaged a little over £584,000, apportioned as follows:—

	Francs.
Roads and Works	4,007,335
Traction and Factories	6,821,185
Traffic	3,265,323
General Service	376,694
Administration	41,747
	14,512,284

HOLLAND.

The Railways in the kingdom of Holland are—

1. The Amsterdam and Rotterdam (Dutch Railway).—The length of the line is 52½ English miles; there are 3¾ miles of double rails. The cost of construction was £905,901, the original capital being £541,666, and loans raised at 4½ per cent. £416,666.

2. The Dutch Rhenish (Amsterdam—Emmerick with Branch from Utrecht to Rotterdam).—Length of line, 109¾ English miles. Cost of construction—Utrecht to Rotterdam, £453,063; Arnheim to Emmerick, £211,903.

3. Dutch Belgian Railway (Moerdyk to Antwerp, with Branch from Roosendaal to Breda).—Length of line 74 English miles. Moerdyk to Belgian Frontier, 18·12 miles; Roosendaal to Breda, 14¼ miles.

4. German, Dutch, and Belgian Railway (Aix-la-Chapelle to Maestricht; Maestricht to Landen).—Maestricht to Belgian Frontier, 2·5 English miles. Length of line, 55·88 English miles; cost of construction, £95,833. Belgian Frontier to Landen, 13·5 miles; cost of construction, £140,000.

HANOVER.

Statistics of Railways, 1st July, 1859.

English miles open, 507·97.

	£
Capital	6,753,177
Gross receipts	704,007
Working expenses	385,831
Net revenue	318,195
Proportion for Hanover	238,564

The following were the lines open in 1859:—

	Length German miles.	Total Receipts. Thalers.	Average per mile. Thalers.
Hanover—Brunswick	5·67	622,441	109,778
Hanover—Minden	8·68	889,468	102,473
Lehrte—Hildesheim	3·34	73,797	22,095
Lehrte—Celle	3·76	204,255	54,323
Celle—Harburg	17·04	809,493	47,505
Wunstorf—Bremen	13·61	617,207	45,349
Hanover and Hildesheim—Cassel	24·00	787,272	32,803
Minden—Emden	34·35	534,338	15,556
	110·45	4,538,273	41,089
		= £680,740	£6,163

DENMARK.

The Railways existing in Denmark and the Duchies are as follows:—

Copenhagen, Roeskilde, and Korsor Line.—Length, 67⅜ English miles; opened to Roeskilde, 27th June, 1847; to Korsor, 27th April, 1856; share and loan capital, £728,466; traffic and income in 1860, £63,050; dividend paid 4 per cent.

Flensburg, Tonning, and Husum.—44½ miles, with a branch to Rendsburg, 35⅔ miles; opened 4th October, 1854; capital, £540,000; income, 1860, £30,202; dividend, guaranteed by the lessees, 6 per cent.

Branch Line to Sleswig.—3 miles 1 furlong; opened 2nd June, 1858; capital, shares, and loans, £27,172; income, 1860, £1,345; has paid no dividend.

Kiel to Altona, Trunk Line.—56½ miles; opened 18th September, 1844; Branches to Rendsburg, 16½ miles; opened 18th September, 1845; to Gluckstadt and Itzehoe, 16½ miles; opened, to Gluckstadt, 19th July, 1845, to Itzehoe, 15th October, 1847. The income on the Trunk Line and Branch to Rendsburg in 1860 was £101,211; 8⅜ per cent. dividend was paid on the Trunk Line, and 6⅜ lease by Trunk Line on the Rendsburg Branch. On the Gluckstadt—Itzehoe Branch no dividend was paid; the receipts were £8,849.

NORWAY.

The railway connecting the Trunk Line from Christiana with the town of Kongsvinge was opened in July last year, a distance of 56 miles, leaving only 21 miles to connect it with the Swedish frontier. For the construction of this section the last Storthing voted the necessary funds; as soon, therefore, as the Swedish engineers decide upon the point of junction with the projected series of Swedish lines, the work will be proceeded with, and when completed, will open a direct communication with the two capitals, which no doubt will tend materially to remove those social and fiscal barriers which still separate the two people.

POLAND.

The railways of the kingdom of Poland are still very incomplete, and the only line actually opened for through traffic is the Warsaw and Vienna Line, with a short branch connecting it with the Prussian railways,

and passing through a portion of the mining districts of the kingdom. This line, which was originally constructed by the Government, was handed over in the year 1857 to a Company, who since that date have continued to work it. Another line, now nearly completed, will connect Warsaw with St. Petersburg, passing through the towns of Bygalastok, Grodno, and Wilna, and joining the direct line (already opened) from St. Petersburg to Berlin, at this latter town. This line has been constructed by a French Company, who obtained large concessions from the Imperial Government, with a guarantee of 5 per cent. on the capital expended, but some disputes have lately arisen between the Government and the Company, which have resulted in the management of the line being taken out of the hands of the Company and placed under the Chief of "Les Ponts et Chaussées." A third line is also in course of construction to connect the town of Bromberg with Warsaw, passing through the towns of Thom, Kuytero, and Lowics, and joining the Warsaw and Vienna line at the town of Skierniewiez. The amount of traffic on the Vienna line has steadily increased both in goods and passengers, and the success of the enterprise may be taken as an earnest of what may be expected for the other lines when opened for traffic. Between 1851 and 1860 the receipts have nearly trebled on this line; the number of passengers has about doubled, and the goods conveyed increased from 3,141,426 poods (of 36 lbs.) to 14,122,181.

The Bromberg Line will, undoubtedly, assist materially in opening out the resources of the country, as it will place the kingdom of Poland in direct railway communication with the port of Dantzig, and thus enable perishable goods to be transported to the only shipping port available for the kingdom without the uncertainty and delay attending the navigation of the River Vistula, and, in addition, the journey from Warsaw to Berlin will be shortened by at least eight hours on its completion.

It is, however, doubtful whether the traffic on the St. Petersburg Line will be sufficient for some years to come to make this a paying speculation.

The first Finnish railway between Helsingfors, the capital of Finland, and Tavastchus, in the interior, was opened on the 17th March, 1862. It is contemplated to unite also St. Petersburg and Wiborg by a railway, but as yet not decided upon, and, according to all appearance, this project will not so quickly be carried out.

The works of the Theodosia and Moscow Railway were suspended in 1861, and all the staff of employés discharged; and there seems, at present, to be little prospect of the works being re-commenced, which will retard the anticipated prosperity of the Crimea considerably, as most of the hopes of the inhabitants were based upon the existence of this line.

PRUSSIA.

Railways in the year 1858.

Lines belonging to the State:—

	Length German Miles.	Capital Expended. Thalers.	Cost per mile. Thalers.
East Line	79·89	26,392,845	330,332
Lower Silesia-Mark	51·70	23,835,000	460,972
Junction Line to Berlin ...	1·34	288,623	215,230
Westphalia—			
Hamm — Paderborn — Landesgr.	17·95	8,803,010	490,418
Munster-Hamm	4·64	1,621,922	349,552
Munster-Rhine	5·12	2,331,315	455,335
Saarbruck	5·92	3,813,107	644,106
Total Lines owned by State	166·57	67,058,822	402,736
Private Lines under State management:—			
Wilhelms Line, including Zweig	21·52	8,056,078	374,353
Upper Silesia.			
Main Line	26·31	13,726,516	521,703
Kattowitz Emmanuelssegen Branch	1·46		
Breslau—Posen—Glogau ...	27·88	11,268,285	404,316
Stargard—Posen	22·64	6,465,182	285,577
Stettin—Stargard	4·57		
Berg-Mark.			
Dusseldorf — Elberfeld — Dortmund	11·23	9,852,986	876,990
Dortmund—Soest ...	7·13	2,755,059	386,025
Prince Wilhelm	4·40	2,211,734	503,812
Aix-la-Chapelle—Dusseldorf Ruhrort.			
Aix-la-Chapelle—Dusseldorf Ruhrort — Crefeld - kr. — Gladbach...	11·43	7,349,138	617,315
Cologne—Crefeld	5·60	3,294,715	588,473
	6·81	1,973,611	289,726
Total Private Lines under State management ...	150·98	66,953,304	460,435
Private Lines under private management:—			
Berlin—Stettin	17·85	7,768,222	346,363
Lower Silesian Branch ...	9·50	2,494,232	262,551
Breslau-Schweidnitz-Freiburg	22·90	8,159,813	356,402
Neisse—Brieg	5·83	1,187,567	203,629
Oppeln—Tarnowitz	10·12	2,367,969	233,989
Berlin—Hamburg	39·66	16,207,123	408,631
Magdeburg—Wittenberge ...	14·29	6,264,836	438,622
Magdeburg—Leipsic, including Schonebeck, Stassfurt, and Stassfurt-Loddeeburg ...	19·36	8,220,108	424,461
Berlin—Potsdam—Magdeburg	19·53	12,953,816	663,040
Magdeburg—Halberstadt ...	7·74	2,546,003	328,729
Berlin—Anhalt—			
Main Line, including Juterborgk-Riesa	30·87	11,436,334	370,588
Dessau—Bitterfeld ...	3·31		
Thuringian, including Weissenfels, Leipsic	29·33	16,928,021	577,039
Cologne—Mindener, including Oberhausen—Arnheim ...	46·70	30,921,774	662,122
Carried over ...	276·99	127,455,818	

	Length German Miles.	Capital Expended. Thalers.	Cost per Mile. Thalers.
Brought forward ...	276·99	127,455,818	
Rhenish Line—			
Herbesthal — Cologne — Rolandseck	17·26	12,601,603	730,104
Rolandseck—Coblentz and Cologne—Ringbahn	6·46	...	...
Aix-la-Chapelle — Maestricht — Hasselt	8·68	5,550,000	639,475
Hasselt—Landen	3·72		
Total Private Lines under private management ...	313·11	145,607,421	478,651
Grand total	630·67	279,646,547	453,830

Lines only partly open :—

Branches of the Upper Silesian Mining Districts	13·03	3,706,358	255,681
Rhine—Nahe	2·01	...	...
Saarbruck—Trier	5·00	...	...

Prussian Lines to 1859.

	No. of Lines.	Length English Miles.	Capital expended.	Cost per Mile.
1850	22	1,738	£22,135,158	£12,736
1851	22	1,747	22,337,221	12,786
1852	23	1,773	23,071,083	13,012
1853	24	1,845	24,894,588	13,493
1854	29	2,257	30,362,106	13,452
1855	29	2,312	31,406,895	13,584
1856	30	2,455	35,295,325	14,377
1857	28	2,680	38,302,854	14,292
1858	29	2,901	41,946,981	14,459
1859	36	3,055	44,141,054	14,449

	Receipts. Total.	Per Mile.	Expenditure. Total.	Per Mile.	Amount of Reserve Fund, &c., at close of year.
	£	£	£	£	£
1850	1,950,661	1,122	928,975	535	294,766
1851	2,142,259	1,226	998,416	572	330,553
1852	2,481,040	1,399	1,163,610	656	397,486
1853	2,782,632	1,508	1,357,525	736	475,644
1854	3,513,691	1,557	1,928,016	854	573,874
1855	4,046,467	1,750	2,297,941	994	584,941
1856	4,587,176	1,848	2,630,853	1,072	621,103
1857	5,201,701	1,941	3,010,305	1,123	766,900
1858	5,244,670	1,808	3,099,993	1,069	807,211
1859	5,054,337	1,654	2,801,154	917	969,915

AUSTRIA.

Commencing with 1827, the system of Austrian Railways had increased as follows :—In 1836 to 34·19 Austrian miles, in 1845 to 141·14, and in 1861 to 756 Austrian miles. These were distributed in forty-four lines, carried on by thirteen companies ; 700 miles more are projected, or in course of construction, so that the Austrian railway system will, in a few years, embrace 1,400 Austrian miles.*

The Emperor Ferdinand Northern Railway and the Charles Lewis Railway connect Poland, Prussia, Silesia, and Russia with the centre of the empire ; the State Railway brings about the communication between Northern Germany and Bosnia and Turkey ; the Southern Lombardo-Venetian and Central Italian Railway join Vienna with the Adriatic Sea and Italy ; the Empress Elizabeth Railway links Vienna with Southern Germany and France ; whilst the rest of the railways accomplish the intercommunication within and without the country.

The following was the length of the various Austrian Lines, and the cost of construction, in the year 1860 :—

	English miles.	Florins. (Standard.)
Emperor Ferdinand's North Line ...	390·00	75,534,087
Austrian North Line	293·31	
„ South East Line	234·63	175,624,868
Vienna New Szoss Line	98·56	
„ Trieste Line	384·75	
North and South Tyrol Line ...	137·75	166,219,016
Lombardo-Venetian Line	232·51	
Vienna-Salzburg Line	210·15	
Lamb-Germund Line...	18·00	64,543,749
Linz-Budveis Line	82·00	64,543,749
Gratz-Koflach Line	23·75	3,322,275
South—North German Junction ...	128·25	20,358,321
Busteradar Line—		
Locomotive Line	13·00	2,520,000
Horse Line	35·63	
Aussig-Teplitz Line	11·88	3,150,000
Brünn-Rossitz Line	14·25	3,150,000
Galician, Carl-Ludwig Line	163·88	24,428,747
Presburg-Tyranau Line	40·00	1,155,000
Theiss Line	363·47	36,547,135
Funf-kirchen Mohae Line	39·19	6,753,092
TOTAL	2914·96	647,850,039
		£64,785,003

SPAIN.

Lines open in the close of 1859 and receipts—

	Length. Miles.	Total Receipts	Per Mile.
Madrid to Alicant and Toledo	299·32	460,270	1,538
Alar to Santandre	56·51	92,760	1,641
Valencia to Almansa	85·70	67,776	791
Cordova to Sevilla	81·35	49,121	604
Barcelona to Arding de Mar ...	22·35	44,118	1,973
Jerez to Trocadera	17·08	38,865	2,275
Barcelona to Saragossa ...	40·98	34,311	836
Barcelona to Granollers ...	18·34	29,717	1,622
Madrid to Saragossa	35·39	21,646	611
Barcelona to Martorell ...	16·76	21,636	1,290
Langres to Gijon	24·22	20,692	854
Tarragona to Reus	8·69	7,931	912
TOTAL	706·69	888,843	

Lines which were in course of construction in 1861—

	Length.	Total Capital.	Government advances.
		£	£
Medina del Campo	54·03	696,346	347,820
Caracagente to Gandia ...	21·11	47,424	
Palencia to Leon and Ponferrara	138·48	1,623,066	811,116
Montfort to Vigo	78·24	.....	705,543
Valencia to Tarragona ...	161·46	2,435,828	670,765

The line of Railway from Barcelona to Saragossa, 365 kilometres, was finished and opened to the public

* The Austrian mile is 8,297 yards.

in the close of 1861; that between Barcelona and the French frontier has been well carried on, and reaches Gerona already, and an understanding having been come to with the French officials for the junction of the two lines, Spanish and French, close to the coast at La Coll de Balitre, it is confidently expected that the remainder will be terminated this year; and, further, the line between Barcelona and Tarragona has already been contracted for, and the contractor has engaged to have it completed before the end of next year.

The Valencia and Saragossa Railway will have a length of 260 kilometres, running as far as the river Ebro, which it will cross on a gigantic bridge, along a rich country, with principal stations in the important towns of Murviedro, Burriana, Castellon, Benicarlo, and Tortosa. With the Government grant, and the liabilities which a recent law allows railways in operation to enter into, upon the security of their stock, the Valencia and Almansa Railway, proprietor of the Tarragona line, will be able to construct it without issuing any shares. The period allowed for completing the railway is four years from the 12th March, 1861. A great deal of work has been done; on the spot no foreign workmen or contractors are employed; but the iron bridges, permanent way, and plant will be English made.

The recent completion of the Madrid, Saragossa, and Alicant Railway put all the north-east of Spain in direct communication with the capital.

Valencia will shortly be joined to Gandia and Denia by means of a tramway, beginning at Carcajente on the Valencia and Madrid Railway. Its length will be 42¼ miles, and the estimated cost is £46,875.

PORTUGAL.

There are three railroads traversing this kingdom under formation and in active progress—from Lisbon, completed as far as Santarem, about twelve leagues distance.

First, Northern Line to Oporto.—The different sections of this line, which it is expected will be finished by the beginning of the year 1864, run in the vicinity of Santarem (finished in 1861), Golegaá, Barquinha, Thomar, Pombal, Coimbra, Aveiro, and Oporto.

Second, East Line to Badajoz.—From Santarem to Golegaá, Barquinha, Ponte de Sor, Crato, Portalegre, Elvas, and Badajoz. Great activity is going on throughout this line, and it is thought that the whole will be completed to Badajoz by the end of this year.

Third, South East Line to Evora.—From Barreiro (south side of the Tagus) to Pinhal Novo, Vendas Novas, Evora, and Beja. This road is finished as far as Vendas Novas, as well as a branch from Pinhal Novo to St. Ubes; the rest is in active progress.

ITALY.

As regards railways this country is in a very backward state. Many lines are projected, which it is earnestly hoped will soon be put in hand; some few are in progress. The following is in brief the present state of railway communication in Italy:—

Railways completed and opened:

	Miles.
Naples to Torre Annunziata	11½
Torre Annunziata to Castellamare	5
„ „ Vietri	17½
	34

The construction of this line from Vietri to Salerno is in a forward state.

Naples to Cancello	13¾
Cancello to Prezenzano	40¼
Cancello to San Severino	26¾
	80¾
Total	114¾

Of the above line, towards the Roman frontier—42 kilometres being the distance from Capua to Prezenzano—were opened to the public in November, 1861.

The undermentioned lines have been sanctioned—

	Miles.
San Beneditto del Tronto to Foggia	153
Foggia to Otranto	192
„ to Salerno	112
Piscara to Ceprano	146
Bari to Taranto...	58
In Calabria	224
Total	885

The first has been commenced, and 12,000 workmen employed on it. Some work is also in progress on the line from Salerno to Foggin.

In the Special Italian Catalogue of the Exhibition of 1862 was given a sketch of the network of railways which covers the Peninsula, in introducing the subject of the factories and the various work performed in them.

In April, 1859, when the first step was taken to unite Italy—up to that period subdivided into seven governments—the position of the railways in the country was as follows:—

Names of the Provinces.	Opened.	In Construction.	Conceded.
Kingdom of Piedmont	807	59	...
Lombardy	200	40	180
Æmilia	33	147	276
Marches and Umbria	...	...	368
Tuscany	308	16	38
Naples	124	4	...
Sicily	...	...	...
Total kilometres	1,472	266	854

A grand total of 2,592 kilometres of railways sanctioned up to that time.

At the breaking out of the war, the people of Tuscany, Romagna, Parma, and Modena, declared themselves for Victor Emanuel, and the Provisional Governments established in Tuscany and Æmilia emu-

lated each other in completing the lines in course of construction, and extending or reorganising schemes of railways already conceded by the Governments which had preceded them.

In far less time than could have been expected, the Central Railway, from Bologna to Piacenza, was opened for traffic. The Ravenna Railway was authorised, and application was made to go on with the necessary works upon the sections of the lines conceded to the Roman Railway Company, which were on the territory already wrested from the Pontificial authority. The Tuscan Government, putting an end to ancient rivalries in respect of petty enterprises, so prejudicial to their own interests, and not less so to the public and to the State, united the four concessionary companies. It proceeded to the junction of the railways, at that time unconnected, to Pisa and Florence; it authorised the extension of the Central Tuscan Railway from Sienna to the frontier of the Pontificial States, near Chiusi, and authorised the junction of two lines previously laid out by a branch from Asciano to Grosseto; and, as the concessionary company of the railway from Florence to Arezzo and Perugia did not fulfil the engagements which it had contracted in the Act of Concession, the Government undertook, provisionally, the construction of that line, and decreed, with equitable indemnities, the forfeiture of their concession.

At the same time, in Lombardy and Piedmont, the construction of the lines decided upon was prosecuted with vigour; to which were added those from Torreberretti to Pavia, the concession of the Ligurian coast lines having remained up to that time inactive, as well as that from Turin to Savona.

In April, 1860, after the annexation of Lombardy, of the Duchies, the Romagna, and Tuscany, which inaugurated the new Kingdom, the state of the railway system was as follows:—

Names of the Provinces.	Open.	In Construction.	Conceded.
Ancient Kingdom of Sardinia ...	107	59	41
Lombardy	200	40	180
Æmilia	180	276	...
Marches and Umbria	...	...	360
Tuscany	308	140	326
Naples	128	...	...
Sicily	...	...	...
Total kilometres	1,623	515	907

A sum total of 3,045 kilometres of railways, for which concessions had been granted up to that time.

Before even the inauguration of the kingdom of Italy, provision was made for the new engagements of the railways of Lombardy and Central Italy, rendered necessary by the treaty of Zurich; and for the line from Reggio to Borgoforte, become, for the moment, unnecessary while the country of Mantua remained under the dominion of Austria, that from Bologna to Ferrara was substituted, with an extension to the Po, so that, being continued ultimately by way of Rovigo and Padua, this last was brought to join the Susa, Milan, and Venice line. At the same time, the construction of the Ligurian railway, from the French frontier to Massa, was guaranteed, being conceded to a large company, and constructed by the State.

At the period of the first meeting of the Italian Parliament, in February, 1861,—

The length of the railways already opened was	1,718 kil.
In course of construction	1,278 „
Conceded	498 „
Total	3,494 kil.

Irrespective of the railways conceded, many companies had made application to Parliament for new lines, and many schemes were submitted for examination, with a view to decide upon their legality or utility. The concessions for which only the sanction of Parliament was required were the following:—

1st. The contract of the 3rd October, 1860, with the Company of Roman Railways, for the lines:—

From Bologna to Ancona.

From Ancona to Rome (section Case-Bruciate-Orte).

From Castel Bolognese to Ravenna.

2nd. The contract of the 13th February, 1861, with the Leghorn Company, for the concession of the line to Porta, the ancient Tuscan frontier, as far as Massa.

3rd. Contract of the 13th of February, 1861, with the same company, for the Florence line, by Arezzo, as far as the junction with the line from Ancona to Rome.

4th. Contract of the 3rd February, 1861, for the modification of the Act of Concession of the railway from Naples to the Adriatic, concluded 24th August, 1860.

All these projects were sanctioned by Parliament, in July, 1861.

5th. The contract of the 25th September, 1860, which confided to a company, represented by M. Adami, the construction of a vast network of railways across the provinces of Naples and of Sicily, which was modified by the Act of the 30th April, 1861, and sanctioned afterwards by a law of the 28th July, 1861.

Finally, by the decrees of the 30th April, of the 12th and the 29th May, 1861, it was stipulated that the works from Ancona to Bologna should be forthwith completed, as also the section Case-Bruciate-Orte (of the line from Ancona to Rome), and of the section Capua-Ceprano (of the line from Naples to Rome), by the Roman Railway Company, to whom the line from Naples to Ceprano (Pontifical frontier), had just been conceded, with an engagement to complete the works of this line, as well as the others, sooner than had been stated, and to undertake the branch line from Cancello to S. Severino.

In order to complete the network of the various lines of central Italy, the extension of the Central Railway of Tuscany, which the Tuscan Government ought to have made through Chiusi, the shortest road between Rome and Florence, was still wanting. The necessity of extending this line of railway as far as the junction of the line from Rome to Ancona, in Umbria, had become manifest; it was accordingly provided for by the agreement of the 19th June, 1861, approved by the law of the 21st July following, by which many different clauses of the previous agreement were modified, with a view of rendering it more in conformity with the scheme generally adopted in Italy. The Government was relieved from the necessity of constructing the railway from Asciano to Grosseto, afterwards conceded to the above company, which thereby was placed at the head of a small group of railways, of an aggregate length of 327 kilometres.

The law of the 17th July, 1861, decreed the construction of the railway from Milan to Vigevano, and authorised that of Vercelli to Mortara, the first of which was obviously indispensable to render available the section already in operation from Vigevano to Mortara, which without this extension, projected from the first, would have always been very onerous upon the State, which had assumed its guarantee and the working of the line.

The Mortara and Vigevano Milan Railway becoming the shortest line of communication between Milan and Genoa, it was more than ever indispensable to give a new exit to the line from Torreberetti to Pavia, the working of which had been undertaken by the State. In order to supply the deficiency so much felt, of direct railway communication from the provinces of Cremona and Brescia with those beyond the Po and with Genoa, the law of the 21st July, 1860, sanctioned the extension of the line in progress from Torreberetti to Pavia, as far as the junction of the two principal lines—Brescia, Cremona, and Pizzighettone and Milan and Piacenza.

It was still necessary to satisfy the reasonable applications of the Sub-Alpine provinces, entertained by Parliament on the 13th July, 1857; it was requisite to create a Trans-Appenine line parallel with the railway from Alessandria to Genoa, and unite, near the sea, those lines which terminate at Turin and Alessandria, and those which run beyond the Alps by the tunnel of Mount Cenis. On the 21st July, 1861, a law was passed, authorising the formation of a railway from Turin to Savona, with a branch starting from Cairo, and forming a junction at Acqui with the section already opened from Alessandria to Acqui. The concession has just been granted to a company, in virtue of the law above mentioned, and of the contract of the 14th November, 1861.

In June, 1862, the Chamber of Deputies discussed and approved the establishment of a line from Alessandria to Brià, which completes the beautiful Piedmontese network, connecting the Sub-Alpine towns in all directions, across a most fertile territory. In order to connect the above-described trunk railways, it is necessary to form, by degrees, the minor lines of the second and third orders. But having regard to the public interest and to the national finances, it was, perhaps, not expedient to undertake them until the greater and more urgent undertakings which had been commenced were more advanced, if not completed; and in the meantime, the surveying of the new lines, and the economical requirements of the various provinces would be studied, and at an opportune moment, the works might be undertaken upon a well-considered and definitely settled plan. It might, nevertheless, be desirable that previously to that time, enterprising speculators should point out the most advantageous lines to construct and work, such as might be obviously indicated by the nature of this beautiful country, the resources of which are so little known.

The present description would, nevertheless, remain incomplete if it did not point out the main lines, as well as the branches, the execution of which it would be undesirable to delay.

In the first place, in order to facilitate the communication between Genoa, Milan, and Switzerland, it would be necessary to form a short junction from Pavia to the Piacenza and Alessandria road, and at no great distance from the Novi and Tortona branch; and, when that long and difficult question of the passage of the Swiss Alps has been resolved, the junction of that important line with the network of the Sardo-Lombard railway can be determined.

The natural course of events will secure the extension of the line of the Tyrrhenian coast as far as Civita Vecchia, and to make a junction at Padua, the railway from Susa to the Po, Alessandria, Bologna and Ferrara, with the Susa and Venice line by way of Milan and Verona. For the completion of the trunk line, running throughout the whole length of Italy, from the Alps to Naples, without approaching either coast, a railway ought to be constructed, which, starting from Orta, or from any other point on the road between Ancona and Rome, would extend to the Pescara and Ceprano line. The central line would leave the Rome and Naples line near Caserta, and, passing by Benevento, would go on to join the Salerno and Foggia line near Conza, to traverse the Appenines, pass through Altamura, Taranto, and Oria, terminating at the port of Brindisi, which is destined to become, at no very distant period, by its position and natural capabilities, one of the most important ports of Italy.

In a strategic point of view, it ought to be considered whether a railway crossing the Appenines would conveniently form a junction with the line of the Tyrrhenian coast and the arsenal of Spezia, with the Italian

Central; and, moreover, whether to connect this arsenal completely with the various fortresses of the great plain washed by the principal Italian rivers, it would be expedient to continue this line as far as the left bank of the Po, and to extend by Mantua the railroad which is about to be constructed from Pavia to Cremona, along this same bank, as far as the junction of the Ferrara and Padua line.

In the Table of Italian railways annexed to this statement, the lines completed, those in progress of construction, and the lines to be conceded are set forth, it being certain, that from the very nature of things, these latter must, after a short delay, be authorised.

In the concession of the principal lines, the main object has been to place the different railways under as few companies as possible, in order not to throw difficulties in the way of their ultimate fusion, according as the various lines might make fresh progress, and their working become more and more organised. A more correct knowledge of the scientific and economical requirements will furnish a solid basis for such arrangements, which may be as profitable to the parties interested as to the Government and the public in general.

The railways in course of construction, or already opened, in the various provinces of the kingdom, are at present appropriated between the Companies and Administrative bodies enumerated in the following Table, drawn up by the Minister of Public Works, and published in an excellent report, from which we have borrowed the principal part of the present statement. The Table also furnishes a good idea of the grouping of the various lines, which, at a more or less distant time, may unite the whole of the railways in the hands of a few powerful bodies, of which the existing companies will form the nucleus.

Lines Open and in Course of Construction.	Opened.	In course of construction.	Under survey.	To be surveyed.	Total. By Lines.	Total. By Companies.	Total. By Groups.
	kil.	kil.	kil.	kil.	kil.	kil.	kil.
Northern Group.							
Turin—Alessandria	91	..	..	..	91	..	..
Alessandria—Genoa	75	..	..	..	75	..	..
Alessandria—Novara	66	..	..	..	66	..	..
Novara—Arona	36	..	..	..	36	..	..
Alessandria—Piacenza	97	..	..	..	97	..	..
Mortara—Vigevano	13	..	..	..	13	..	..
Genoa—Voltri	15	..	..	..	15	..	..
Lines belonging to or worked by the State: Turin—Cuneo (without reckoning 13 Kil. on the Alessandria line)	74	..	..	..	74	..	..
Savigliano—Saluzzo	16	..	..	..	16	..	..
Cavallermaggiore—Bra	13	..	..	..	13	..	..
Turin—Pignerol	38	..	..	..	38	..	..
Alessandria—Acqui	34	..	..	..	34	..	..
Novi—Tortona	19	..	..	..	19	..	..
Terrebertelli—Parma	47	..	..	..	47	..	..
Turcello—Casale—Valenza	42	..	..	..	42	676	..
Lines in course of construction, the working of which might be united with the foregoing: From Arona to the Swiss frontier by Oscola	..	60	..	..	60	60	..
Savona—Carmagnolo	..	..	114	..	114	..	..
Lario—Acqui	..	..	47	..	47	161	..
Voltri to the French frontier	..	145	..	..	145	..	..
Genoa—Spezia	..	..	97	..	97	232	..
Vigevano—Milan	..	..	..	29	29	..	..
Bra—Alessandria	..	..	..	83	83	..	..
Lines belonging to and worked by the Victor Emmanuel Company: Susa—Turin	83	..	..	..	83	..	..
Turin—Sagenta	116	..	..	..	116	..	..
Chivasso—Ivrea	32	..	..	..	33	..	..
Sanabia—Biella	30	..	..	..	30	..	..
Turin Junction	5	..	..	..	5	..	..
Lines in course of construction: From Susa to the French frontier (Bardonnèche Tunnel)	..	6	39	..	45	282	1,523
Carried forward ..	913	298	312	..	1,523	1,523	1,523

TABLE—*Continued.*

Lines Open and in Course of Construction.	Opened.	In course of construction.	Under survey.	To be surveyed.	Total. By Lines.	Total. By Companies.	Total. By Groups.
	kil.	kil.	kil.	kil.	kil.	kil.	kil.
Brought forward	913	298	312	..	1,523	1,523	1,523
Group of the Valley of the Po.							
Magenta—Milan—Peschiera	169	..	..	..	169	..	..
Milan—Camerlata (Comm)	45	..	..	..	45	..	..
Lodi—Galbiate ..	27	..	..	..	27	..	..
Lines belonging to and worked by the Lombardy and Central Italy Railway Company: Milan—Piacenza ..	66	..	..	..	66	..	..
Piacenza—Bologna	147	..	..	..	147	..	..
Bologna—Ferrara	47	..	..	..	47	..	..
Ferrara—Ponte Lagoscuro	5	..	..	..	5	..	..
Milan—Pavia ..	..	31	..	..	31	..	..
Bergamo—Lecco ..	..	36	..	..	36	..	..
Treviglio—Cremona ..	..	60	..	..	60	..	..
Gallarate—Sesto Calende	..	..	17	..	17	..	..
Bologna—Pistoja ..	..	98	..	..	98	747	..
Peschiera—Venice ..	141	..	..	..	141	..	..
Ditto in the Venetian Provinces: Verona—Mantua ..	36	..	..	..	36	..	..
Verona—Trente ..	98	..	..	..	98	..	..
Trente—Bolzano ..	85	..	..	..	85	..	..
Mestre—Cormons, limit of the Province d' Udine	148	..	..	..	148	475	..
Lines surveyed by the Government to be conceded to private enterprise, the working of which may be united to that of the same group: Brescia—Cremona ..	..	..	43	..	43	..	..
Cremona—Pavia ..	..	..	74	..	74	132	..
Pavia to the Po (not authorised) ..	..	..	..	44	44	44	1,382
Central Thyrenian Group.							
Florence—Pisa, left bank	80	..	..	..	80	..	..
" " right bank	98	..	..	..	98	..	..
Lines conceded to the Leghorn Railway Company	19	..	..	..	19	..	..
Pisa—Massa ..	42	..	..	..	42	..	..
Junction at Florence ..	3	..	..	..	3	..	..
Florence—Montevarchi ..	..	40	..	..	40	..	..
Montevarchi—Foligno ..	..	152	..	..	152	431	..
Lines conceded to the Central Tuscany Railway Company ..	150	..	..	..	150	..	..
Orbial—Arte ..	..	81	..	..	81	..	..
Asciano—Grosseto ..	..	96	..	..	96	327	..
Various Lines, the working of which may be combined with the above Companies ..	..	205	..	..	205	..	..
Leghorn—Chiarone ..	..	..	..	..	..	205	..
Cecchina—Rigle—Volterrone	..	28	..	..	28	233	..
Massa—Spezia ..	..	40	..	..	40	40	..
Chiarone—Civitavecchia ..	..	..	85	45	45	45	1,076
Central Roman Group.							
Bologna—Ancona ..	206	..	..	..	206	..	..
Lines held by the Roman Company and worked by them in the Kingdom of Italy: Naples—Pescarana ..	93	..	..	..	93	..	..
Cancello—San Severino ..	43	..	..	..	43	..	..
Pescarana—Cepmano ..	86	..	..	..	86	..	..
Castel Bolognese—Ravenna	..	41	..	..	41	..	..
Case Bruciate—Orte ..	..	191	..	..	191	627	..
Rome—Cepmano ..	122	..	..	..	122	..	..
Ditto, in the Roman Provinces: Rome—Civitavecchia ..	73	..	..	..	73	..	..
Railroad round Rome ..	13	..	..	..	13	..	..
Rome—Frascati ..	10	..	..	..	10	..	..
Orte—Rome ..	..	84	..	..	84	301	..
Government Line, the working of which ought to be connected with the above ..	..	15	22	..	37	37	965
San Severino—Avellino ..	..	..	15	22	37	37	965
South Neapolitan Group.							
Ancona—S. Benedetto del Tronto ..	..	90	..	..	90	..	..
Santo Benedetto—Pescara ..	..	71	..	..	71	..	..
Pescara—Foggia	..	175	..	..	175	..	..
Foggia—Barletta	..	..	72	..	72	..	..
Barletta—Bari	..	..	..	82	82	..	..
Bari—Brindisi	..	..	..	105	105	..	..
Lines constructed by the State: Brindisi—Lecce ..	..	..	..	40	40	..	..
Lecce—Otranto ..	..	..	..	32	32	..	..
Pescara—Turri ..	..	..	29	..	29	..	..
Turri—Popoli ..	..	..	26	..	26	..	..
Popoli—Solmona ..	..	..	..	18	18	..	..
Solmona—Cepmano ..	..	..	..	161	161	..	..
Foggia—Portici San Venere ..	..	..	50	..	50	..	..
Ponte San Venere—Eboli ..	..	..	101	..	101	..	..
Eboli—Salerno ..	..	30	..	..	30	1,006	..
Line conceded to the Bayard Company: Napoli—Salerno ..	48	4	..	..	52	..	..
Castellamare Branch ..	8	..	..	..	8	60	1,116
Calabro Sicilian Group.							
Lines to be constructed by the Government on the Continent ..	..	..	79	..	79	..	..
Massafra—Taranto ..	..	..	15	..	15	..	..
Massafra—Reggio ..	..	..	50	363	413	507	..
Paterno—Trabia ..	..	46	..	..	46	..	..
Trabia—Catania ..	..	..	69	130	199	..	..
Ditto, in Sicily .. Giarenti Branch ..	..	..	..	40	40	..	..
Messina—Catania ..	..	..	76	..	76	..	..
Catania—Syracuse ..	..	..	..	90	90	430	937
Lines in the Island of Sardinia.							
Cagliari—Oristano ..	..	..	..	93	..	..	..
Oristano—Bosa	..	..	..	42	..	..	..
Bosa—Tolovo	..	..	..	85	..	..	..
Lines in the Island of Sardinia: Tolovo—Gulf of Orange	..	..	..	72	..	..	..
Tolovo—Sassari ..	..	..	..	45	..	..	..
Sassari—Porto Torres ..	..	..	..	19	..	..	..
Sassari—Alghero ..	..	..	..	44	407	407	407
Total Kilometres	2,944	1,912	1,628	1,931	7,415	7,415	

SUMMARY OF LINES.

	Opened.	In course of construction.	Under survey.	To be surveyed.	Total.
	kil.	kil.	kil.	kil.	kil.
Lines surveyed or opened by Government	676	693	657	1,035	3,061
Groups owned or opened by Private Companies ...	1,576	1,135	369	485	3,576
Total	2,252	1,828	1,026	1,531	6,637
Lines conceded to the Lombardo-Roman Company in the Venetian and Roman Provinces	692	84	...	...	776
Total kilometres...	2,944	1,912	1,026	1,531	7,413

Some details of the receipts and expenses in 1861 of some of the Italian railways may be here inserted:—

Sections opened by Government.	£
Genoa and Arona line (270 kilometres), gross receipts	554,885
„ „ receipts per kilometre ...	2,055
Piacenza line (116 kilometres), gross receipts ...	113,310
„ „ receipts per kilometre ...	9,760
Cuneo and Saluzzo line (103 kil.), gross receipts ...	79,913
„ „ receipts per kilometre ...	775

Sections opened by the Victor Emmanuel Company.	£
Turin and Ticino line, net revenue per kilometre ...	1,419
„ „ expense per kilometre ...	572
„ „ net profit per kilometre ...	846
Lombard group, gross receipts	262,221
This group has cost, in construction and purchase of plant	3,005,325
Po Valley group, gross receipts	148,460
Construction and purchase of plant	2,928,630
Leghorn group, gross receipts	154,935
Construction and purchase of plant...	2,533,993

Venetian and Tyrolese Railway. The net receipts on this line, after deducting expenses, were, in 1860, £157,912, and in 1861, £245,186. The line from Casarza to Udine was opened on the 2nd July, 1860, and from Udine to Nabresina on the 3rd October of the same year.

The Roman railways now working comprise 340 miles of railway. The line from Civita Vecchia to Naples, traversing Rome, was to be in entire operation in July, and the line from Bologna to Ancona, completed by the branch from Castel Bolognese to Ravenna. The line from Rome to Ancona is to be finished by the end of 1864.

THE RATIONALE AND PRACTICE OF PERMANENT WAY.

TIMBER.

In the olden time, in New York, ere steam was on the ocean, a Broadway boarding-house proprietor reckoned a permanent boarder at a dollar per diem, and calculated a transient at two and a half.

Very similar to this is the case of railway proprietors, who get transient way from the contractor, after bargaining for permanent way at too low a price, the only thing permanent about it being the permanent expense. In fact, it is merely a piece of trade nomenclature to distinguish it from the temporary way, which the contractor takes away with him when he has made the line, leaving in its stead occasionally something even less efficient, having regard to the work to be done.

At the outset, contractors' way was very much what it is still—flat-bottomed rails, or rails in chairs, laid on cross-timbers, in the form of a primitive ladder. Scoffing at this, the early engineers devised a system of what was grandly called "Permanent Way," the timber being replaced by large blocks of stone; but this proving less permanent than the temporary, it was abandoned, and the latter reigned in its stead.

Why did the stone blocks fail? First, because they had an insufficient amount of bearing area for their height and weight. Secondly, because they had no tie across, to keep the gauge, or efficient longitudinal tie in the rail-fastening to prevent fore-and-aft movement. Thirdly, because their effect was that of huge anvil-blocks, 3 cwt. each, giving effect to all blows on the rail in the form of destruction. Fourthly, because the attachment of the rail to the chair was a bad fit, and subject to get loose, producing what mechanics call "knock"—an unfailing source of progressive destruction, as all persons know who have the care of steam-engines. "For want of a nail the shoe was lost; for want of a shoe the horse was lost," and so on. So, for want of a fit and a fastening, the rail got loose as the stone block subsided unevenly on its base of clay or ballast, and then came the succession of blows with every wheel, like the action of a forge tilt-hammer.

The fallacy in all this was the assumption that the stone block bedded only by the bumping force of men, equivalent to the "three-men beetle" of Sir John Falstaff, was a fixed and immoveable base. To make the base immoveable, the stones should have been built together into a wall, with a foundation of concrete, and this, supposing no subsidence below, would still be the best preparation for a railway of large and heavy traffic.

But the isolated stones lay on an infirm and rocking base. Two holes drilled half through, were filled with oak trenails $1\frac{1}{2}''$ in diameter. The stone trimmed

down to a surface, received the cast-iron chair, which was fastened to it by two iron spikes driven into the plugs, and the rail was fastened into the chair by a wedge of wood, with a minimum of bearing area. Thus the continuance of the rail in position depended wholly upon the position of the stone block. If the block sunk vertically under the bending rail, the elastic reaction would suspend the block. If the block sunk laterally, the elastic action would recover it from its distorted position, as each wheel left it in succession. This process repeated, gradually caused the spikes to become loose pistons, working up and down in the oak plugs, or permanently drew them, so that rail and chair were in the very best position to produce successive blows. The old blocks still exist among the *débris* of railways, showing the excavations on their surfaces, "jumped" out by the chairs to depths varying from half an inch to an inch and a half, according to the hardness of the stone.

There was a lack of mechanical instinct and perception in the engineers who followed each other like sheep, in laying down so impossible a system. Nature, who never permits with impunity, any departure from her laws, corrected the evil; the faulty system would not work in practice, the stone blocks were removed, and wood again reigned. The blocks were misused!

"But," say the sticklers for timber, "the experiment was fairly and fully carried out by Jesse Hartley, who built a pair of solid granite walls, and laid rails on them, and that they failed, not from subsidence, but from rigidity."

We have great respect for the memory of Jesse Hartley, as a man who knew his own mind and followed its bent; but, nevertheless, he did not try the experiment fully or fairly. He omitted one important element, a motionless fit. The wheels jumped on the rails, and the rails jumped on the granite and crushed, and the chairs were fractured, and all went to ruin.

Reasoning from this and other similar facts, railway engineers have got into a habit of decrying rigidity. Robert Stephenson once illustrated this at a meeting of the Civil Engineer's Institution, by describing a piece of line in what are called the Camden Town Tunnels of the London and North Western Railway, a solid cutting where the ballast lay superincumbent on the clay, without the access of water. The rails, apparently unaccountably, got rapidly destroyed in this position after being some time in use. Various reasons were assigned for it; but at last the sleepers were taken up, and the ballast below was found hard as a solid rock. It was dug up and made loose, and the evil was remedied.

It is well known that the pleasantest travelling per rail is over a newly laid line, with plenty of ballast, in which the sleepers lie soft and fairly bedded, while rails, chairs, and joints are all firm. This is said to be elastic; but is a misnomer. There is no elasticity in sand or ballast, it is simply plastic; and when it is so rammed together that it fits the sleepers throughout, it becomes as a solid rock or block of stone, with the difference that the chairs rest on five inches of timber instead of directly on to the stone, as in the primitive method. The timber serves also to dull the ringing sound between the wheel and rail, which usually takes place when iron sleepers are used in direct contact with the rail.

Cast-iron sleepers, badly fitted, are neither better nor worse than the old stone blocks, *per se;* but they may be made better or worse by having a better or worse form given to them to maintain their position in the ballast, and cast-iron is a material affording a better scope for good form than stone does.

The name "sleepers," taken from the house builder's vocabulary, means a large scantling of timber that "sleeps," or is immoveable in the position assigned to it. The timber under a wall or floor fulfils this condition; but the sleepers on railways rarely sleep at all, unless during the intervals of trains, and even then it will be mostly found that they are partially separated from the rails, and rise and fall with them, and that they rock fore and aft with the action of the wheels. The elevation from the bottom of the sleeper to the top of the rail is twelve inches. The width of the sleeper on the ballast is only ten, and the width of the packing cannot well be more than eight; so that there is practically an elevation of twelve inches to a base of eight; and the only thing to prevent this base from rocking fore and aft,—the framing it as it were to the rail,—is the chair and inefficient wood key, which grinds away its surface and gets loose. As the sleepers rock fore and aft, an open channel is formed on each side in the ballast, to admit water to the base, and churn up mud and dirt in the form called "slurry," leaving the washed gravel with a concrete surface. The sleeper beds in rainy weather are practically mud pits, with stone bottoms.

Men are employed to keep permanent way in order, i.e., to restore its level when sunk, by lifting the sleepers and packing ballast beneath them, i.e., they ram below the sleeper certain pyramidal hillocks in detached portions, which the trains gradually level by compression. It is a process which would be called by builders "underpinning," and very skilfully it is done; but there is little more than half the sleeper area, which takes a real bearing on the ballast. The middle portion is not packed at all; lest it should rock end for end, and spring at the mid-length. To be in any way efficient, as at present used, the scantling of the sleepers should be at least 12″ × 12″ instead of 10″ × 5″, to give them a chance of sleeping instead of dancing.

But there is a great disadvantage in having the bearing of the sleeper far below the surface of the ballast. In order to pack the sleepers to restore the level, it is necessary to "open out," i.e., get to the lower bearing

to "pack." In bad weather this is scarcely possible, as it would be making the permanent way a series of sleeper ponds, and then covering the surface with absorbent ballast, like a garden-bed of soft and porous material.

Two classes of rails are used on the transverse sleepers—the double-head, used in chairs, intended to reverse when worn on the top surface, and the foot, or contractor's rail, fastened direct to the sleepers without chairs. One important element in a rail, is depth to resist flexure, and in proportion to the depth the breadth of base should increase, to prevent overturning. An ordinary double-head rail and chair rise 7 in. above the sleeper, and the spread of the chair varies from 12 to 14 in. or above double the height. The foot-rail in America, when cross sleepers are used very close together, is usually from 3″ to 3½″ in height, and 4″ in breadth of foot. The English foot rail was about 4″ high and 4″ wide in base, and being found vertically weak, was increased to 5″, with a base of 6″, at a time, when the destruction of the double head-rail in chairs was found so great under the heavy engines, as to make reversal impracticable; but when efficiently made to prevent the foot from bending, or the rail from oversetting, the cost of the single-head became great. And the fastenings, mere spikes, driven in at the edges, with a lip over them, are also inefficient to keep the rail firm. And if holes be pierced through the lower rib, the rail is weakened and apt to "kink." The advantages of the foot rail are, that it is laterally stiff, and not being in contact with an iron-bearing surface, it is less liable to become crystalline under the blows of the wheels, as do the rails used in chairs, a defect so prevalent that the Government officers discountenance the practice of reversal, and in case of a broken rail, usually inquire first—"if it has been reversed?" i. e., in case of the breakage being followed by a result of killing or wounding any one not belonging to the Company.

The earliest rails of wrought-iron, single-headed and fish-bellied, were 35 lbs. per yard. The fish-bellying was a remarkable result of following existing practice, as sheep do in narrow passages, the bell-wether setting the type of the leaping spot. The earliest rails were of cast-iron in three-feet lengths. They were, in fact, short girders stretching from fixed points or piers, and were made fish-bellied just as furnace bars and drain gratings are. When the wrought-iron succeeded the cast, they were made continuous fish-bellies from sleeper to sleeper or block to block, on the assumption that the blocks were fixed piers or unyielding supports. When the fallacy of this assumption was made clear in locomotive practice, the fallacy of the fish-bellied practice disappeared with it. Engines increased in weight, and rails increased in weight, first 56 lbs., then 60; 65 was, for a long time the standard, then 70 and then 75. One assumed authority was accustomed on all occasions to issue his dictum—"with a good 75 lb. rail, a 28 lb. chair, and plenty of cross sleepers, it is difficult to make a bad permanent way." But practice belied the dictum, and rails crept up to 85 lbs., and, as a maximum, to 92 lbs.; chairs which began at 14 lbs. each, have gradually grown to 42 lbs.; and sleepers, which were 8 in. and 9½ in. round have now become timber 9 ft. long, 10 in. wide, and 5 in. deep, as a standard, and a very inefficient one.

For a long time the rail ends were supposed to be made a continuous connection by being placed in a chair 5 in. and 6 in. broad and keyed together with a piece of wood 7 in. long, 2 in. thick, and 2½ in. deep, the bearing area in the chair being about 6 in. super each rail. A broad chair was deprecated as tending to tilt, and the theory almost amounted to supporting the rail ends on knife edges to prevent tilting; the result was, that passengers counted the rail joints while travelling, by the succession of jolts. This became at last unbearable, and a proposition was made to "fish" the joints, i. e., to place bars of iron in the side channels of the rails, so so to make them continuous. For a long time there was an outcry against this, but at last the experiment was tried, and the result was that high speed travelling became practicable. We doubt whether any driver would dare to run an engine at 60 miles per hour on a line with the old joint chair fastenings.

This then is permanent way—so called—of the national standard gauge, 4 ft. 8½ in.; an odd measurement arising from the fact that the measure was originally outside the rails, or an integral 5 ft., the width of the rails being 1⅜ in. each. When it was found necessary to widen the rails, that could not be done internally, the real gauge being the wheel flanges, 4 ft. 8½ in., so the thickness was added externally, leaving the outside gauge 5 ft. 1½ in.

So permanent way, in its highest phase, now consists of an 84 lb. rail, a 42 lb. chair, creosoted sleepers 9 ft. × 10 in. × 5 in. centres of sleepers 2 ft. 6 in. apart, fish-joints and compressed oak keys, and two iron spikes per chair, saying nothing of ballast. Let us see what this amounts to per mile, single, for the mere material without labour.

	Tons.	cwt.		£		£	s.
504 Rails, 84 lb. yd. ...	132	0	at	8	say	1,056	0
504 Fishes	6	6	„	8	„	50	8
2,116 Bolts	1	17	„	20	„	37	0
4,224 Chairs, 42 lb.	79	4	„	4	„	316	16
12,672 Spikes	5	13	„	12	„	67	16
4,224 Oak keys compressed, 2*d.*						35	4
2,112 Sleepers, 4*s.*						422	8
						£1,985	12
But iron rails are now being given up, and steel is being substituted, which will be extra £8					... say	1,056	0
Making the total per mile						£3,041	12
Or in round numbers, per *double mile*						£6,000	

So far as we have dealt with the national gauge, or, as we may call it, the accidental gauge, which would, by

the common consent of engineers, have been a gauge of 5 ft. 6 in., as in all our colonies, and in Spain and elsewhere, had the present knowledge existed at the outset. Leaving the Irish gauge, which was said to be a result of adding together six several gauges and taking their mean, we will now consider the question of the broad gauge, and its system of structure.

The gauge is 7 ft. integral, and was devised, it is said, with the intention of lowering the bodies of the vehicles between the wheels, and so keeping a low centre of gravity; but this idea was soon abandoned, and the frames were put above the wheels, as on other lines, with no advantage whatever from the wide gauge; the vehicles, which might have been 14 ft. in width, being only nine, on account of the tunnels, a width no greater than has been obtained on the narrow-gauge.

There can be no doubt that breadth of gauge is an advantage for steady running; but, with the existing structure of wheels and axles, the friction is enormously increased by the breadth of gauge, especially on curves, and the weight and cumber of the vehicles is also increased, without corresponding advantages.

It has been frequently remarked that travelling is easier on the Great Western than on the narrow gauge, and it is attributed to the breadth of gauge. But is is much more a result of the structure of the line. The bridge rails are 6 in. wide on their bearing flanges, and they lie upon longitudinal continuous timbers without chairs. When the line is new, and in good order, the result is great smoothness.

In the structure, longitudinal half balks of timber, 14 in. wide and 7 in. deep, are abutted end to end under each line of rails. The bridge rail is about 3½ in. deep, making a total depth of 10½ in. by 14 in. breadth. The rails are secured to the timbers by bolts passing through the flanges into nuts below the base of the timber, the nuts being 4 in. by 2½ in. to give a bearing surface sufficient to prevent them from sinking into the timber, which they do notwithstanding. Now, just as the transverse sleepers of the narrow-gauge have a tendency to rock fore and aft, so the longitudinals of the broad-gauge have a tendency to rock laterally. To prevent this, they are framed to transverse timbers, with tenons to the inside edges of each, and tie bolts to keep them together.

So long as this frame does not rock and the rails do not press into the timber, all goes on tolerably well; but the process of destruction is nevertheless sure. The bridge rail proper has no connecting fish at the joints. The ends are merely bolted down on a piece of thin flat plate, which gradually sinks. Moreover, the rail is too weak vertically, and sinks in detail into the timber length-long with the grain, loosening all the bolts, by drawing the nuts into the timber below, with the flexure. And the pressure of the wheels causes the longitudinals to rock laterally the transverse timbers notwithstanding, just as the narrow gauge system rocks fore and aft, and so the tie-bolts get strained, and the nuts pulled in, and in the process of packing the ballast gets rammed tightest at the timber edges, involving a new difficulty. The rails under the wheel pressure take the form below of an obtuse wedge, by the flanges bending upwards, and thus split the longitudinal timbers from end to end. Upon a worn line the roughness and rattle of the rails up and down on the bolts, becomes nearly as bad as the rattle of rails in chairs.

Time was that there was a great outcry on account of the rotting of sleepers, which question resolved itself into the fact that mere rubbish was used in the form of small saplings. Good timber was not so liable to decay, and in a position where it was always wet or always dry, would last fifteen years. Then came in the practice of creosoting the more spongy kind of wood, making it chemically durable, for creosote is of no use to really good timber, as it will not penetrate. But under the increased load of engines, chemical durability is no longer a question. It is mechanical destruction that takes place, by the chairs driving into the sleepers, under the pounding process, and this is one of the reasons why chairs have grown from 14 to 42 lbs. to increase their bearing surface. A sleeper of soft American timber when creosoted, acquires a consistency something like a bar of hard soap, and chairs are driven in to the depth of an inch or two, and we have seen them driven quite through after long use. And with the bridge rails on the longitudinal system, longitudinal grooves are formed; and we remember the case of a provincial engineer, who beholding for the first time longitudinal way under repair, asked gravely and quite innocently, "why do you groove your rails into the sleepers?"

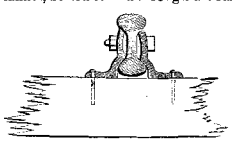
It is this mechanical destruction of the timber sleepers which has led to the many attempts to substitute iron for them in England. It is chemical destruction by sun and rain, more than white ant, which has rendered it absolutely necessary to substitute iron for timber in India and similar regions.

"But," say the superintendents and engineers of English lines, "though we would gladly use iron sleepers, we find practically that iron way is rigid, and the rails and rolling stock are more rapidly destroyed than where timber is used for sleepers." We need the elasticity of timber."

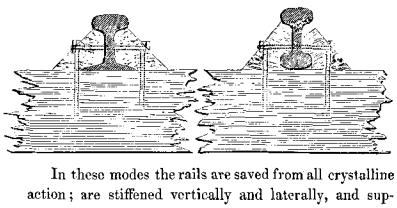
But the elasticity of timber between the chair and solid ballast beaten into concrete not being sufficient, a practice has obtained to some extent, of making a kind of well, in the seat of the chair, and putting therein a piece of hard timber to bed the rail on to prevent damage, as the rail works loose. But these pieces of wood require constant renewal.

A better practice is to suspend the rail in the chair by its upper rib, and not allow the bottom to touch.

A better practice still is to dispense with the chair altogether, and apply instead a pair of brackets, one in each rail channel, bolted to and through the rail, suspend-



ing the rail between them. In this mode, 12lbs. of cast-iron, or 8lbs. of wrought-iron, with a bolt, are the substitute for 42lbs. of cast-iron, and a wooden key, and the bottom table of the rail is saved from damage. Or wooden brackets may form a continuous bearing for the rail, and serve also to connect it firmly to the sleepers.



In these modes the rails are saved from all crystalline action; are stiffened vertically and laterally, and supported in case of fracture.

But there still remains the difficulty that the ballast will harden into a concrete under the sleepers, by the blows of the wheels. This is the ultimate condition of ballast on a solid foundation—the normal result,—and to prevent this result, by disintegrating the ballast from time to time needs a large quantity of human labour.

Now the more solid the foundation, other things being equal, the easier should be the maintenance of level. The object then should be how to utilize this solidity, rather than how to destroy it.

At the basis of the outcry against rigidity there is a truth; it may be illustrated by two several well-known facts.

Firstly. The permanent way which is most permanent, i. e., least destroyed by the running of *trains*, is that which lies elastically in boggy ground.

Secondly. The permanent way which is most rapidly destroyed by the running of the trains, is when the ground is rendered hard and solid by the action of frost. These cases are so many crucial instances. The roads which were comparatively good are suddenly rendered bad by rigidity. This is evidence beyond dispute.

To get rid of the rigidity by rendering the ballast plastic for a short time, is simply making a road more likely to get out of order by losing its level.

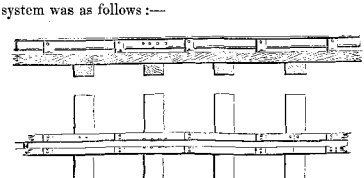
To proceed logically, let us inquire by what process a well laid cross sleeper line gets out of order? What is the process of destruction?

It begins with the running of the engines and trains. The rail deflects under the engine wheel, which thus applies its force to each sleeper in succession, instead of distributing it over two or more sleepers. It is like driving nails one after the other.

The remedy for this would be first, to enable the rail to distribute the load over two or more sleepers, and, secondly, to substitute an elastic action between the rail and sleeper, for the plastic action of the ballast below the sleepers; the first process would be equivalent to doubling the area of each sleeper, or taking from it half the load. The second process would permit of the sleepers being solid immoveable blocks of stone or iron, or timber, brick, or concrete; and this plan is not difficult of execution. The ordinary sleepers may be overlaid with longitudinal timbers spiked or trenailled down to them, making thus a long ladder-like frame, the joints abutting where they occur, at the centre of each sleeper. On these longitudinals the chairs may be placed spaced in the intervals between the sleepers, and the rails applied in the usual manner. The sleepers are packed hard and solid, but the longitudinals are not sleepers, but only elastic bases for the chairs, and have no packing, the spaces being open for drainage.

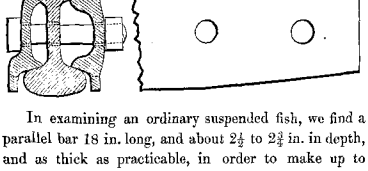
In this mode it will be seen that the sleepers cannot rock fore and aft, being firmly secured to the longitudinals, and that the load transmitted to them elastically through the chairs, can never press on a single sleeper, but on two or more at the same time, and thus the sleepers may be of iron or any other rigid material, not subject to perish chemically; moreover, the lateral firmness is greatly increased by the longitudinals.

Having satisfied himself of the truth of this principle by comparison with an analogous plan for other purposes, the writer laid it before many professional men to find out what objections could be made to it. The system was as follows:—



A peculiar form of fishes was devised with several objects. First, to give vertical strength at the joint equal to the solid portion of the rail. Secondly, to stiffen the joint laterally. Thirdly, to obtain an elastic fit throughout, constantly tending to tighten.

Fourthly, to keep the bolts tight; and, Fifthly, to remove waste material from the fish ends, where not wanted, and apply it at the joint where it is wanted.



In examining an ordinary suspended fish, we find a parallel bar 18 in. long, and about $2\frac{1}{2}$ to $2\frac{3}{4}$ in. in depth, and as thick as practicable, in order to make up to some extent by extra thickness what is wanting in depth. It is evident that in applying a load the mid-lengths will be the weakest part, and therefore the metal should taper towards the ends, or the effects will be mischievous, thickening the metal where not needed, and thus producing the effect of a blow at the weak joint. And in the process of punching a large hole in a thick narrow bar, distortion of form is induced, giving projections at the bolt holes and want of fit against the rail; yet more, the absence of elasticity in the bar renders it very difficult to keep the bolts tight. Lateral strains, produced by the action of the wheel flanges, slightly stretch the bolt or the thread, and it is constantly loose, as there is no reacting elasticity.

The cut below, *Fig.* 1, shows this class of fish, and *Fig.* 2 shows an attempt made to amend it by greater thickness and depth. The maximum depth of Fig. 1 is $2\frac{7}{8}$ in., that of Fig. 2 is $3\frac{5}{8}$ in. apparently, but not really, for the thin edges afford no resistance—buckling instantly under flexure—while the strain on the bolt is greatly increased by the want of efficient shoulder bearing. Turning to the elastic ribbed fishes, it will be seen that the total efficient depth in the centre is $4\frac{3}{4}$ in. while the shoulder bearing is an angle of repose.

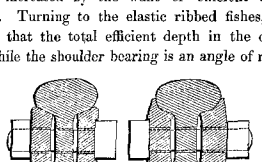


Fig. 1. Fig. 2.

In the deep tapered fishes the metal is comparatively thin, and arched where the bolts pass through, and the outside fish is nearly as deep as the rail at the centre, the inner fish being reduced at top for the wheel flanges to pass. The manufacturing process is simply rolling, cutting off to lengths, shearing or stamping off the taper, and punching the holes, in which process no distortion can be produced, on account of the thick internal ribs. Probably the new process by hydraulic pressure will simplify the manufacture. In screwing up, the bolt-head is prevented from turning round by the outer rib of the inside fish, and as the nut tightens the fish-arches flatten and force the internal ribs against the rail tables above and below. The elastic resistance prevents any tendency of the nuts to get loose.

In this mode the rails may really be made continuous bars, of equal strength throughout, and thus the sleepers may be equally spaced, an important consideration in economic maintenance of way, not attainable with the ordinary fish, in which the weak joints need external help by the approximation of the sleepers.

The opinions obtained by the writer from practical men, in discussion, were as follows:—

Resident Engineer, No. 1.—"On my line I find that the ballast and substructure are gradually growing harder and more solid under the running of the trains, and that the sleepers are getting worn out mechanically by the driving of the chairs into the timber, and the rails and fastenings suffer rapid destruction. We have endeavoured to help it by occasionally rebedding the sleepers in new ballast, but it is of very little use, and I am seriously thinking of taking up all the sleepers and replacing them in the intervals. Our chairs are now increased in size and weight, and we are adopting the practice of suspending the rail in the chair by the upper table; I think this elastic system is likely to supply the conditions requisite for permanence in the way, and the principle of the improved fish is evidently right."

Resident Engineer, No. 2.—"There can be no doubt that this elastic system is right as to principle; but my line works well, because we have an extra number of sleepers, which distributes the strain and saves the spring of the rails. As regards the fishes, I am satisfied that had they been produced at the outset, the present form would never have been used. But we hate alterations, on account of the labour and trouble involved in any change."

Resident Engineer, No. 3.—"I like your permanent way very much; your new road is a move in the right direction; elasticity and not rigidity is what we want to make a good road, else why is such damage done when all is hard with frost? Again, elasticity will nearly double the life of rails."

Resident Engineer, No. 4.—"I still use slips of wood on my iron way, and in a new road should double their thickness. Rails do wear out rather faster on iron than on longitudinal timber. The bolts give out even with the timber packing, but without the timber there would be no keeping them at all. I like your idea of a ballastless road. I believe that a permanent way laid on timber bedded on masonry would answer well, and save a great deal of money in the long run. I like the *theory* of continuous bearings, but practice upsets one's notions."

Consulting Engineer, No. 1.—"After thinking much over this elastic system, I am satisfied that it is right

in principle, and can find no objection to it, save the extra quantity of timber required."

Resident Engineer, No. 5.—"There is no doubt whatever that this line would be out and out the most permanent way yet tried, smooth and free from blows, and the sleepers would sleep."

Assistant Engineer.—"The effect of this elastic system would evidently be easy running, like a new line in good order, before the ballast has got hard."

Mechanical Railway Engineer.—"There cannot be two opinions of that line. With equal amounts of material it must produce double the durability of line laid in the ordinary method, and with equal durability a smaller amount of material would suffice. It is difficult to understand why so obvious an advantage should have been so long overlooked."

So much for theory. But theory needs the verification of practice, and a sample of practice has been obtained which has verified the predictions of theory. For a considerable time a small sample has been laid on a Metropolitan main line, over which 120 trains work daily, with engines of 32 tons weight, with passengers, goods, coal, and at the highest rates of speed with several of the passenger trains. The sleepers do not move on the ballast, and the elastic base gives an equable vibration without any blows. The opinion of the engineers is unequivocally in its favour, and the following is the verdict of—

Two Engine Drivers.—"The very best piece of road we ever drove over."

There is a prevalent superstition that ballast is an essential part of a permanent way. But we incline to believe that it is simply a contrivance for low cost way which cannot be permanent, by reason of constant subsidence. Ballast is no more adapted for permanent way than gravel, which serves well for garden walks, would be adapted for London pavements. In a long line with few trains, the outlay for a really permanent way might be too great; but on brick viaducts, with increasing traffic, it is a marvel that the slovenly ballast has not long since given way to a permanent surface of impervious stone or brick, not subject to destruction by the interposition of an elastic base, and free from the annoyance of dust in dry weather, and mud in wet weather. The evil of ballast is prominent enough on viaducts, where the constant ramming forces out the retaining walls and parapets, and ought to force a better system on the consideration of the authorities, even without regard to the vertical blows which are constantly disintegrating the arches.

With regard to first cost, the consulting engineer alluded to referred to the extra quantity of timber as being wholly an excess. But this is not quite a correct statement. Rails have grown from 35 lbs. to 84 lbs. per yard, because of the rigidity of the way. But on a continuous elastic system, a rail of 70 lbs. capable of better manufacture, will be more than equal to an 84, and brackets of 14 lbs. will be demonstrably better than chairs of 42. Now, let us see the comparison of quantities.

	Tons.	Cwt.			£	s.
504 Rails, 70 lbs. yd.	110	0	at	8 say	880	0
505 Fishes	6	6	„	8 „	50	8
2,016 Bolts	1	17	„	20 „	37	0
3,520 Pairs of Brackets, 14 lbs. ...	22	0	„	4 „	88	0
3,520 Bolts	1	13	„	20 „	33	0
7,040 Spikes	3	3	„	12 „	37	16
1,760 Cross sleepers, 4s.	—			—	352	0
1,174 Ditto for longitudinals ...	—			—	287	0
3,520 Trenails, 2d.	—			—	29	7
					£1,794	11
If steel rails extra...				£8 say	880	0
					£2,674	11
Or in round numbers, per double mile					£5,350	0

So that there appears an economy in first cost of £650 per double mile, equal to 11 per cent. saying nothing of maintenance and saving to rolling stock, in comparison with what is now called first-class permanent way.

But if it turns out that iron rails under elastic treatment become as durable as steel rails under rigid treatment, the saving would be equal to £2,400 per double mile.

So far we have dealt with this question as regards timber roads. We propose hereafter to deal with the iron ways which are likely to take their place, at least so far as substructure is concerned.

WEST LONDON EXTENSION RAILWAY.

BRIDGE OVER THE THAMES AT BATTERSEA.

DESCRIPTION.

Plates 20, 21, 22, 23, and 24.

This bridge carries the West London Extension Railway (which connects Kensington with the Victoria, Pimlico, Station) over the Thames, near Battersea. It was designed by Mr. William Baker, C.E., of the London and North Western Railway Company, and was constructed under the superintendence of Mr. William Lawford, C.E., by Messrs. Brassey and O'Gilvie, contractors. It comprises five river openings of 144 ft.

span each in the clear, rise of arches 16 ft., affording 720 ft. of waterway (as shown on plate 20); and ten land arches, each of 40 ft. span, four on the Surrey, and six on the Middlesex end of the bridge. The foundations of the piers and abutments are 36 ft. below the Trinity high water mark, 20 ft. below low water mark, and 14 ft. below the bed of the deepest part of the river. These piers were constructed in coffer dams, the inner piles of which were not less than 5 ft. from the outer edge of the bottom course of masonry (Plate 22, Figs. 2 and 3).

Each of these piers stands on a bed of concrete 2 ft. thick, and extending 3 ft. beyond the lower course of footings, upon which is laid a course of York landings 12 in. thick, extending 1 ft. beyond the lower course of footings. The foundations are carried up in brickwork to within 2 ft. of the bed of the river, from which point to the springing, the pier is faced with picked faced ashlar of Derbyshire stone. (See Fig. 3, Plate 22.)

The abutments are built similarly to the piers, except that they have brick footings and hollow chambers. (See Figs. 4, 5, and 8, Plate 22.)

All stonework above the springing is tool dressed. The piles were cut off at the level of the bed of the river, and the space between the coffer dam and the brickwork was filled with puddled clay, carried up to a height of 3 ft. above the bed.

The concrete was composed of five parts of gravel to one of blue lias-lime, the gravel to contain as much coarse sand as would make that portion of lime into mortar; all the mortar was composed of two measures of sharp sand to one of blue lias-lime.

Each of the river arches is composed of six wrought-iron ribs arranged in pairs, 2 ft. 6 in. apart. (See Plate 23, Fig. 1.)

The voussoir is formed of $\frac{3}{8}$ in. plates, 39 in. deep at the springing, and 30 in. deep at the crown, with double angle iron (each $3\frac{1}{2}''$ by $2\frac{1}{2}''$ by $\frac{1}{2}''$) top and bottom, to which the flanges are attached by means of rivets, the bottom flange is 18 in. wide by $\frac{1}{2}$ in. thick, the top flange 16 in. wide by $\frac{1}{2}$ in. thick. The top of the rib is a horizontal parallel girder (see Plate 22), similarly composed, and 24 in. deep at the pier and to its intersection with the voussoir, diminishing to 18″ at the crown. This voussoir and top girder are connected by a lattice spandril, composed of 7″, 6″, and 5″ by $\frac{1}{2}$ in. **H** and double **T** iron, the latter rivetted together thus, $\frac{1}{\top}$; to which is added a stiffening bar, following the same curve as the voussoir. Each pair of ribs is connected near the haunches, by means of three frames composed of angle iron, crossed-braced, and rivetted to the ribs, and thus forming an open box girder. This principle is continued up to the crown of the arch, where the voussoir and top girder unite in a double cell.

The three pairs of ribs are braced together at the haunches by means of trellis transverse girders, 2 ft. 6 in. deep, and are secured together at the top by the cross girders, 10 in. deep, and placed 4 ft. apart, which support the roadway. These cross girders are formed of a centre web of iron, the bottom of which is flanged with double angle iron, and the top with double channel iron, on the lower flange of which the buckle-plate flooring rests. (See Figs. 1 and 7, Plate 23.)

The whole is again cross-braced by diagonal rods, bolted to a centre plate and to brackets rivetted on to each of the angles. (See Fig. 1, Plate 23.) Figs. 2, 3, 4, 5, and 6, Plate 23, show the mode by which contraction and expansion is provided for. Fig. 4 is a front, and Fig. 5 is a side elevation of cast-iron standards, two of which are bolted down to the stonework of the pier, and united by a cast-iron frame secured with bolts and nuts. These standards have recesses to receive the ends of the horizontal girders, as shown on plan, Fig. 3, and elevation, Fig. 2.

These standards secure the horizontal girders in their position at the same time, allowing for horizontal motion, and a bed and bearing plate, planed parallel, are fixed under the end of the horizontal girders, upon which it slides, as shown by Figs. 2 and 6.

A cast-iron moulding (Plate 24, Fig. 3) is attached to the horizontal girder throughout its whole length, and a cast-iron plinth is bolted on the top of the same, on to which the ornamental cast-iron parapet, shown in elevation, is fixed, the whole being surmounted by a wooden handrail (see Fig. 3).

The following statement exhibits the quantity of material, and the cost of the bridge, including the land arches:—

2,000	Cubic yards of Concrete	£585
1,100	„ „ Brickwork	11,000
130,000	„ feet Stone	19,500
2,150	Tons of Wrought-iron	46,500
356	„ Cast „	4,500
Cofferdams, &c.		20,000
Timber in platform, handrail, &c.		1,500
Sundries		415
TOTAL		...£104,000

This bridge stood a very severe test with a load of 300 tons (i. e. 150 tons on each line of road) going at the rate of forty miles per hour in the same direction, the deflection was about $\frac{7}{8}$ of an inch.

DEFENSIVE ARMOUR FOR SHIPS OF WAR.

Plate 25.

PERHAPS no engineering question of modern times has engaged the attention of the scientific world for the past three years to the same extent as that of armour for the protection of ships of war. Indeed, ever since the iron-plated floating batteries of the French made their *debut* at Kinburn, the question has been regarded with no secondary interest. Still, it was not till the Special Committee on Iron, better known as the Iron Plate Committee, commenced their experiments, that the engineering mind of Britain seemed thoroughly impressed with the importance of the question, and the contest between ordnance and armour, then in its skirmishing stages, became one of the most exciting topics of the day. How keenly this contest was maintained by those for the defensive, is illustrated by the fact, that upwards of 600 plans and propositions relating to armour for ships of war have been laid before the Iron Plate Committee and the Admiralty. Nor were the proposers nameless men. Could the list be published, it would be found that, as far as engineering prestige is concerned, "England knows no higher names" than many in that army of inventors. Among those whose plans have already been tested under the auspices of the Committee at Shoeburyness, are the names of Fairbairn, Hawkshaw, Scott Russell, and others well known to British engineering.

In 1859 experiments were made on 4-in. armour plates attached to the side of the "Trusty," which was equal in scantling to that of a wooden line of battle ship of 90 guns, as represented in Fig. 1. But it was left for the Iron Plate Committee to systematize these experiments, by the adoption of a certain fixed method. The conditions proper to this method, adherence to which must be strict before results can be fairly compared, appear to be the following:—A type or standard target considered as the unit of resistance; a constant range; the same or equal guns; similar charges of powder, and weight of projectiles; and, an identical order of firing, whether in single discharges or salvos. It is such predominance of method which alone can give to the operations conducted at Shoeburyness the character of *experiments*. The present standard target is the "Warrior target," Fig. 2, which is almost a copy of the armour of "La Gloire," Fig. 3, with the addition of grooving and tongueing the armour plates, which, however, has been found to be no improvement, and therefore abandoned.

Before proceeding to notice the different systems experimented on, it may be interesting, first to glance at the ordeal originally devised for testing them. The following table, compiled from the programme of rounds fired at the "Chalmers target," will serve to illustrate the character of these tests; for, though the Committee in their recent experiments have departed from the usual programme, thus destroying the comparative, and, consequently, the practical value of the test, still, as only two targets have hitherto withstood the entire programme, the following figures are not wholly devoid of interest:—

Number of Rounds.	Nature of Ordnance.	Charge of Powder.	Nature of Projectile.	Weight of Projectile.	Total weight of Metal.	Work or Power (in Foot-pounds. (Above numbers.)
3	110 pounder	12lbs.	Shell filled with sand	104 lbs.	312	6,500,000
3	110 ,,	12 ,,	,, ,, ,, powder	104 ,,	312	6,500,000
2	68 ,,	16 ,,	,, ,, ,, sand	49½ ,,	99	5,000,000
2	68 ,,	16 ,,	,, ,, ,, powder	49½ ,,	99	5,000,000
6	110 ,,	14 ,,	Solid cast-iron	110 ,,	660	13,000,000
2	110 ,,	16 ,,	,, ,, ...	200 ,,	1,200	9,250,000
4	68 ,,	16 ,,	,, ,, ...	66½ ,,	265	10,250,000
1	110 ,,	16 ,,	Steel flat-ended shot . .	109 ,,	109	1,000,000
27	..	..	.. ..	..	3,056	57,000,000

Here we have 27 rounds of heavy ordnance, throwing 3,056 lbs. weight of metal, propelled by 456 lbs. of powder, including the bursting charges of the live-shell, and exerting a power equal to the lifting of 25,000 tons one foot high. But how many of the naval armour targets have actually survived this terrible test? only two, as already stated, the "Warrior," and the "Chalmers" targets. The majority of the others struck their colours before the battle was half fought. Figures 1, 2, and 3, are illustrations of the first rude ideas that took form and existence as naval armour; and, notwithstanding the amount of engineering talent of the highest order that has been applied to the question, and the expenditure of £70,000 of public money in attempts to discover a better method, nothing has been accomplished by the authorities, and this rude and worthless system is still the best that the Iron Plate Committee can recommend, or the Admiralty adopt, for the protection of the navy. True, a better, and more economical system was recently devised and tested at great expense by a private citizen, for which the inventor gets nothing but the thanks of the public through the press. Indeed, the Government frown down and discountenance all individual efforts, and, it is quite probable that nothing but disaster in actual warfare will lead to the adoption of any plan, however excellent, if originated outside of the Admiralty. The grand defect of the "Warrior" system, judging from the trial of the "Warrior" target, is the inability of the wood-backing or surface on which the armour-plate rests to support it under the impact of heavy projectiles. Such timber surface, of the area of a 68-pounder shot,

will crush under a pressure of 50 tons; but the work in this projectile, at the point of impact, is 2,565,000 foot-pounds, or, about 1,150 tons. Thus the backing does not resist 5 per cent. of the blow, so, that, a 68-pounder, solid shot, will crush the timber through a 4½in. plate into several inches less space, and either break the bolts, or leave them so loose as to be useless as fastenings. When this target was taken to pieces, thirteen through bolts were found to have been broken in the timber, being one for each shot at a high velocity that struck the target. Hence, taking these experiments as a guide, the "Warrior," if engaged by a ship of her own class, at close quarters, and rolling in a sea-way, would have a plate knocked off by every broadside from her antagonist. Fig. 4, Mr. Hawkshaw's system, was a crude attempt to substitute thinner, and, consequently, cheaper iron for heavy rolled or hammered plates. And, although the Government thought so highly of the plan as to order the construction and trial of two expensive targets simultaneously, the first shot from the Regular Service 68-pounder gun settled the question, and proved that the desired end—economy—was not to be attained in the manner proposed by Mr. Hawkshaw. The fact that the Americans, with more perseverance than wisdom, have persisted in plating so many of their iron-clads upon a similar principle, is sufficient to account for the disasters that have attended so many of their expeditions. Figures 5, 6, and 7, were constructed with a view to ascertain if the timber-backing might be dispensed with altogether; and, like many other projects, their respective trials proved only one point satisfactorily, namely, that they would not answer. Fig. 5, the Committee's own target, constructed by Messrs. Fairbairn and Co., of Manchester, was, in reality Mr. Fairbairn's target, being the same principle amended and improved (?) which had been twice tried before at the public expense. This target had a greater depth of frame than any of its rivals, which was expected to compensate for the lightness of the armour proper. But the fastenings proved faithless, three fourths of the bolts having broken close to the nuts before the programme was half expended. In short, the target was easily destroyed by the regular 68, and 110-pounder guns. Mr. Samuda, Fig. 6, expected to overcome the tendency to buckle by securing the edges of the plates to a 2½ in. bar which lapped the joint inside; but he only added another to the long list of failures, for, he evidently overlooked the fact that the prime cause of buckling is the deflection of the plate when struck in the middle, and that the only means of obviating this is to give such stiffness to the backing as will prevent the plate from being driven into it. The peculiar and complicated fastenings of the Scott Russell target, Fig. 7, were intended to obviate the evils which the inventor contended were chiefly attributable to through bolts, such as fracturing, and the consequent loss of lateral strength and resisting power. But, strange to say, of all the targets that have been tried at Shoeburyness, the plates of this were fractured the worst, thus failing most signally in the very feature it was constructed to improve. Thus, failure succeeded failure; and the Government, wearied and worried (as a writer in the *Army and Navy Gazette* observes) "by the tedious aggravating assaults of small inventors, or by the sleuth dog-like attacks of the larger mechanical bores" turned at bay. The Chairman of the Iron Plate Committee had the unpleasant duty to announce to Parliament that with all their labour and vast expenditure they had been able to devise nothing better than the "Warrior system," and Mr. Fairbairn, addressing the Royal Society, receded from the defiant position, which, as champion of the defensive, he assumed in his contest with Sir Wm. Armstrong in 1861, and frankly acknowledged that the guns had the best of the day, and nothing remained for the partizans of armour but "to begin their work *de novo*."

Meanwhile, certain inventors, who were not easily convinced that their schemes were wholly worthless, disregarded the armistice proclaimed by the Admiralty, and pushed their plans before them as perseveringly as ever; but, although some of these were strongly recommended by the Iron Plate Committee, nothing would induce the Admiralty to re-open the question. However, the persevering efforts of one inventor attracted the attention of Sir Samuel Morton Peto, M.P., who generously gave him a target at his own expense and risk. The "Chalmers target" opened the contest afresh, the Committee and the Admiralty following suit with another somewhat similar in principle, but which, like all their former projects, proved a wretched failure, whilst that of their rival proved a triumphant success; still, the lesson taught them by private enterprise is ignored, and another costly target, at the public expense, will shortly enter the lists. But, whatever advantages to science, or the public service, may result from these resuscitated experiments, the credit is undoubtedly due to the success of the "Chalmers target." This target, Fig. 8, tried on the 27th of April last, is the first since the "Warrior" trial on the 21st of October, 1861, that resisted the entire programme. But, whilst the latter was almost destroyed, the former was but little injured; and even after the addition of two rounds, at a subsequent trial, from the 300-pounder gun with 50 lb. charges, its resisting powers were scarcely impaired. The compound backing, A, B, gave such support to the armour plates that the buckling, heretofore so detrimental to plates backed by wood only, was effectually prevented, whilst the cushion, C, protected the frame and fastenings from the baneful effects of vibration which have proved so destructive to rigid targets. Comparing these targets, the *Mechanics' Magazine* says:—

"The trial of this target must be regarded as a remarkable success. It stood the brunt of the firing throughout better than the 'Warrior' target. In the crowning test—the salvo of five great guns, concentrating 466 lbs. weight of metal, at a high velocity against one plate, over an area of about 2 ft. square—it carried away the palm. A similar salvo, fired at the 'Warrior' section, fractured and buckled the plates extensively, and broke or loosened six or seven bolts."

Fig. 9, the Stevens Battery, and Fig. 10, the once famous "Merrimac," are specimens of transatlantic armour plating, where the difficulty of obtaining heavy solid plates, may account for the adoption of a system known to be defective. The last target tried by the Admiralty, at the recommendation of the Iron Plate Committee, had, in common with the Chalmers target, iron on edge supporting the armour plates; but, as the ribs in this case bore both upon the plate and the skin of the ship, the result was, destruction to the interior fastenings, for the work in the projectile passed along the rib with like effect to lightning along a conductor, which does not terminate in the earth, but in the wall. It is to be regretted that the cupolas of the "Royal Sovereign" are plated upon a plan similar to the target which proved so faithless on the 7th of July last, and which the *Times* justly remarked "was known to be little better than worthless before it was put up." The whole question of plating ships of war is still in its infancy, for, notwithstanding the fact that the highest engineering talent in the kingdom has been devoted to it for several years, there has been, according to the *Times*, "only one target tested, that has fulfilled all the requirements of strength so needed and so long sought for—the Chalmers target"—since the Iron Plate Committee began their interesting and expensive experiments.

LAMBETH SUSPENSION BRIDGE.

DESCRIPTION.

Plates 26, 27, 28, and 29.

THE work which is illustrated by plates 26, 27, 28, and 29, is, at the present moment, one of peculiar interest. The student of the progress of Modern Engineering will have traced the construction of bridges through the stages of arched viaducts composed of stone and brick, until the increased facility in the manufacture of iron suggested the possibility of substituting girders of cast-iron, carrying a platform for the solid arch. Still the arch form was maintained for all bridges of large spans. He will then come to the period when the rude constructions of the inhabitants of China and the Himalaya Mountains of India, suggested the mode of passing over chasms and rivers by means of a suspended way, and will commence his investigation of the use of iron for that purpose, in the bridge across the River Tees in England, about the year 1741. A period of upwards of half a century elapsed, however, before this instance of the use of iron for suspension bridges, led to its introduction as part of the stock-in-trade of the Engineer; and the principle reached its crisis in the erection of the Menai Bridge by Mr. Telford. Up to this period the smallness of the bridges of this description, had not made it necessary to study, with any accuracy, the actual strength of the iron employed, but Mr. Telford had engaged in an undertaking which could not be designed without an intimate knowledge of the strains to which every part of the structure would be subject, and the capabilities of the different descriptions of iron to resist these strains. A most valuable series of experiments were accordingly undertaken by Mr. Telford, to ascertain the strength of cohesion of malleable iron, and also of iron wire, tables of which were published by the late Professor Barlow. From this period the suspension bridge became an acknowledged principle for road bridges of large span, and met the difficulty experienced in devising a mode of crossing spaces, where, from the impossibility of obtaining foundations for piers, or from other causes, very large spans became necessary. Thus far the suspension principle for bridges had shown itself to be, in many cases, the most convenient, and, in large spans, the most economical, mode of bridging rivers, &c., but the introduction of the system of railways for general traffic, in the construction of the Liverpool and Manchester line, soon put the principle to a test, which, until a very late period, has thrown a doubt on its applicability to railway purposes, owing to its oscillation, undulation, and general unsteadiness under sudden and unequal pressure, and the accumulation strains which these causes brought to bear on the several parts. This doubt originated, or was confirmed, by the failure of a bridge on the Stockton and Darlington Railway; but it appears that its construction was so imperfect, that no opinion of any value could be based upon it. The objection, however, has scarcely been overcome to the present hour, for,

although the possibility of suspending a rigid platform has been urged for some years by the engineer of the work which forms the subject of this article, and a railway suspension bridge was actually being worked over the Niagara River in North America, the doubt had apparently fixed itself too firmly in the minds of English engineers to be easily removed.

In 1857 Mr. Peter Barlow designed a rigid suspension bridge to carry the Enniskillen and Coleraine Railway, and the High Road bridge, over the River Foyle, which was examined and approved of by Sir Wm. Cubitt, and adopted by the Commissioners. Mr. Barlow, in July, 1860, read a paper on the subject before the mechanical section of the British Association, which gave rise to such contradictory statements regarding the Niagara Bridge, before mentioned, that he determined to visit and inspect that bridge himself. He accordingly went to America and made experiments, which fully confirmed his opinion of the feasibility of constructing a rigid suspension bridge. His observations on these experiments he published on his return to England.* This brings to the work which forms the subject under notice, namely, a bridge to carry a carriage road, and double footway, over the Thames, to connect Church Street, Lambeth, with Market Street, Westminster, about midway between Westminster and Vauxhall Bridges. Mr. Barlow's description of the intended bridge is as follows:—

"The principle of construction proposed to be adopted is a combination of iron cables with lattice girders; which principle has been proved by recent experience to form the most durable, safe, and economical distribution of the material in an iron structure, and has been used in America for aqueducts, and in railway bridges, to the extent even of a span of 800 ft., as well as for ordinary road traffic."

The bridge consists of three spans of 268 ft. each in the clear. The roadway, which is 31′ 9″ wide, and is adapted for a double carriage and a double footway, being suspended from twenty-eight iron wire cables, passing over the summits of four wrought-iron towers, two of which stand on piers in the river, and the other two on abutments on either bank. (See Plate 25, Figs. 1, 2, 3.)

The towers on the piers are 32′ 10″ in height, and those on the abutments 28′ 11″, with a base in each case of 10′ 0″ × 5′ 0″ tapering to 7′ 0″ × 3′ 0″ at the top. The covering plates at the joints are 5″ × $\frac{3}{8}$″.

In the towers which stand on the piers (See Plate 27, Figs. 2, 8, 9) 30′ 4″ of the height is divided into three cells, which again are divided horizontally, at intervals of 6 ft., by floors. The whole is constructed of $\frac{1}{4}$″ boiler-plate, strengthened at the angles externally by 2$\frac{1}{2}$″ × 2$\frac{1}{2}$″ × $\frac{3}{8}$″ angle iron, and internally at the meetings of the division by similar angle iron (See Plate 27, Figs. 2, 3, 8, 9, 10, and 15), the floors are supported by 5″ × 2$\frac{1}{2}$″ **T** iron. The joints of the plates are connected by 5″ × $\frac{3}{8}$″ covering plates. In the towers which stand on the abutments 24′ 3″ of their height has the two outer sides formed each into two cells 1′ 6″ wide, which, together with the centre portion of the tower, is built similarly to the pier towers. The centre space of these towers is divided horizontally by floors at every 9 ft. (See Plate 27, Fig. 3 and 10).

The upper part of the towers above the heights before mentioned are merely wrought-iron casings to cover the cradles. Each pair of towers is connected by a hollow arch constructed of boiler-plate, the sides being 1′ 6″ apart. (See Plate 27, Figs. 5 and 14.) Each pier tower contains 240 square inches area of iron to resist compression, the dead weight which it has to sustain being one ton to the inch, and the weight with the moving load two tons to the inch, or equal to 1,440 tons on the entire length of the bridge, and stands on two columns, each formed of a cast-iron cylinder. (See Plate 26, Fig. 4.) The columns, like the towers, are in pairs, and connected below the floor of the bridge by a strong cast-iron plate forming an arch. Their construction is as follows:—The exterior is a cast-iron cylinder of 12 ft. diameter and 1$\frac{1}{4}$″ thickness, cast in segments. The upper portion is only 3 ft. in length; and being designed with an ovolo and astragal, forms a capital to the column. Like all the lengths, it is cast in six pieces, which have flange joints 3 in. deep, both vertically and horizontally. The cylinders below the capital, are all in 9′ 6″ lengths, and are connected by 1$\frac{1}{4}$″ bolts, at a pitch of 5$\frac{1}{2}$″ horizontally and 6″ vertically. There are brackets cast between all the bolt-holes. Each segment is likewise strengthened by a vertical rib of the same depth and thickness at the flanges. These cylinders are sunk to a depth of 18 ft. below the bed of the river, by weighting and excavating from the inside, they are then filled with concrete to within 4 ft. of the bed of the river, and 1 ft. of solid brickwork is added, on which an inverted dome is formed, from which a lining of brickwork, 3 ft. in thickness is carried up to within 3′ 3″ of the foundations of the towers. Here another domed arch is built, and a solid foundation formed to receive the bed-plates of the towers. (See Plate 26, Fig. 4.) Both the concrete and the mortar for the brickwork is made with Portland cement. This mode of constructing the brickwork hollow, ensures more careful and systematic work, and admits of examination, and, of necessary repairs. Broad cantilevers are bolted round the head of each of the columns which carry the footpaths round the towers, and also serve as supports for the mains of the Lambeth Gas Company. (See Plate 25, Fig. 11, and Plate 26, Fig. 4.) The abutments for carrying the shore towers are dissimilar on

* Observations on the Niagara Railway Suspension Bridge, by Peter W. Barlow, C.E., F.R.S., F.G.S., John Weale, 59, High Holborn.

the Westminster and Lambeth ends of the bridge owing to the very different nature of the ground. That on the Lambeth shore is entirely of brickwork, it is 48 ft. long by 32 ft. wide, built in cells (see Plate 28, Figs. 2, 4, 5, 6), and is sunk to a depth of 16 ft. below high water mark. The ground on the Westminster side of the river, however, is of a very treacherous nature, and the abutment has, therefore, been made to consist of a solid ring of brickwork, 8 ft. thick, standing on a foundation of cast-iron caissons (see Plate 28, Figs. 1, 7, and 10). These caissons consist of twelve boxes without bottoms, each box being formed in three tiers, and the whole bolted together vertically and horizontally, so as to occupy the same space of 48×32 as the Lambeth abutment, and enclosing a space in the centre of $32' 0'' \times 16' 0''$. These caissons, together with the square space enclosed by them, are filled with concrete.

The cables are twenty-eight in number, and are arranged in four groups of seven each. Two of these groups, placed side by side, support the suspension rods on each side of the bridge. Each cable is 3′ 0 in. in diameter, and consists of seven strands, and each strand of seven wires $\frac{1}{10}$ of an inch in diameter. Each cable weighs 36 lbs. to the yard, and has been tested to a strain of 40 tons to the sectional inch; these twenty-eight cables afford a section area of 100 square inches of wire, and are capable of bearing a strain of 4,000 tons, which is guaranteed, though the greatest strain that can possibly come upon the bridge is only 720 tons when fully loaded, and 360 tons when at rest. These groups of cables pass over the cradles which are fixed on the summits of the towers (see Plate 27, Figs. 4, 6, 7, 11, 12, and 13), and also over saddle-pieces fixed on the upper part of the brickwork of the abutments (see Plate 28, Figs. 1, 3, 4, 6). On the Lambeth side, the cables are passed down to within a short distance of the three upper mooring girders, they are then turned back for a distance of 7 ft., and formed into a loop by means of five shackles or clips; this loop holds a thimble, through which passes a steel eye-bolt; this eye-bolt is passed through a hole in the upper mooring girder, beneath which it is secured by a nut (Figs. 3, 11, and 12, Plate 28), shows this arrangement, Fig. 11 exhibits those for receiving the fourteen cables on each side of the bridge, each of the loops were tested with a strain of eighty tons, being four times as much as they will ever be required to bear. Adjustment of the cables are provided for, as shown in Fig. 12, Plate 28, by the connections, by means of rods and nuts, of the upper, with three corresponding lower transverse girders; these transverse girders are held down by three longitudinal girders, built into the brickwork on the Westminster side. Owing to the limited depth allowed by the caisson there are only three transverse mooring girders, to which the eye-bolts are immediately attached, the longitudinal girders being held down to the caissons by rods and nuts (see Figs. 1, 8, and 9, Plate 28). The roadway consists of two box girders, 2 ft. 3 in. in depth, by 18 in. wide of $\frac{9}{16}$ in. plate transversing the whole length of the bridge, immediately under the suspension cables (see Plate 25, Figs. 3 and 4), between these box girders, transverse girders, 14 in. deep and of $\frac{1}{4}$ in. plate, are rivetted to the main girders, 4 ft. apart, carrying the roadway, which is formed of wood blocks bedded in pitch on a wrought-iron flooring. To the outside of the box girder, cantilevers, formed of bar-iron, are rivetted, which carry the footpath, composed of slabs of Portland stone. This footpath is greatly strengthened by a wrought-iron lattice girder serving the office of a handrail. One of the peculiarities of this structure is the mode in which the roadway is suspended to the cable, which is exhibited on Plate 25, and consists of lattice and vertical suspension rods, and diagonal bracing, shown by Figs. 1, 3, 9, and 10. These suspension rods and diagonal braces meet and are attached to the cables by means of saddles, shown in elevation and section (Figs. 7 and 8); these saddles are made in two pieces, having the inside moulded to fit the groups of cables, which they are made to clip by means of bolts and nuts. The diagonal bracing passes into the top of the pier towers, and are bolted to cellular plates, fixed for the purpose (see Plate 27, Figs. 1, 2, and 9). On the top of the abutment towers the diagonals are fixed to the cradles (see Figs. 7 and 11), and are carried down to the mooring plates in the abutments (see Plate 28, Figs. 1, 3, 9, 11, and 12). Another peculiarity of this bridge is, that no provision is made for expansion or contraction, the whole of which is absorbed by a slight rise and fall in the floor.

In this bridge the engineer has deviated from the usual mode of using iron wire for the purpose of suspension, the cables being made of twisted strands instead of wire formed into hanks, as in the Freiburg and other bridges (and, therefore, only subject to direct strain); it may be apprehended that such a mode of construction cannot but be subject to a liability to stretch, which would not only involve the displacement of the roadway, but would likewise bring an unequal strain upon the diagonal bars. The weight of the bridge is 240 tons per span, or 720 tons for the three spans, and the cost, exclusive of approaches and parliamentary expenses, will not exceed £35,000. The parliamentary expenses and purchase of land will not exceed £10,000; and, should the outlay be kept within this amount, it would certainly verify the assertion of Mr. Barlow, quoted in the early part of this article, that it is the "most economical distribution of the material in an iron structure." At present the accounts have not been finally adjusted, but we hope on a future occasion to be able to give a detailed account of the outlay.

THE ALLEN ENGINE.

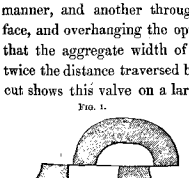
Plate 30.

This engine was introduced to the notice of European engineers at the International Exhibition of 1862, where it attracted much attention, and received a very general verdict of approval. The valves and valve-movements are the invention of Mr. John F. Allen, of New York. The engine was designed by Mr. Charles T. Porter, engineer, of New York, and the illustrative drawing made by Mr. E. H. Aydon.

This engine belongs to the class known as variable-expansion engines; the distinguishing feature of which is, that they have no regulating valve, but the full attainable pressure of steam is admitted to the cylinder, and the governor, in case of varying resistances, regulates the speed by changing the point of cut-off,—and to that division of these engines, in which the valves have positive movements, as distinguished from those, not much known in England but extensively employed in the United States, in which the valves are worked by liberating gear. The description of this engine divides itself into two parts; first, the description of the valves and valve-movements; and, second, that of the general arrangement and construction in detail of the whole engine. The form and action of each part will be considered with reference to the objects which it is designed to attain, and also to that theoretical excellence, towards which the progress of modern engineering is steadily tending.

1. *The valves.*—These, as will be seen by reference to the sectional plan, Fig. 5, are four in number, two at each end of the cylinder. The form of the valve is such that it uncovers simultaneously two passages for the steam into one port, one past the end, in the usual manner, and another through a cavity formed in its face, and overhanging the opposite edge of the seat; so that the aggregate width of opening made is equal to twice the distance traversed by the valve. The following cut shows this valve on a larger scale than the plate:—

FIG. 1.



In the employment of slide-valves, it is usual for one valve to perform the four *functions* of admitting, cutting-off, releasing and confining the steam, and if an additional valve is employed, it is for the purpose only of cutting-off the steam, leaving the remaining operations to be performed by the principal valve. In this engine these functions are distributed differently; at each end of the cylinder, one valve admits and cuts-off the steam, by opening and closing the induction-port, and another, by the same action on the eduction-port, releases and confines it, and thus one controls the flow of steam before, and the other that after, it has done its work in the cylinder. Each of the induction-valves consists, in fact, of two of the valves just described, united in one casting, and opening and closing four passages into two ports, which afterwards unite in one. The advantage of this great area of opening, which gives, when running at high speed, a pressure in the cylinder closely approaching to that in the boiler, and enables this to be maintained quite up to the point of cut-off, is well understood by engineers.

It will be observed, that the valve is not what is called a gridiron-valve; but is of such a nature, that, when the port is open at all it is in equilibrium, except the portions projecting to cover the ends of the ports. The extreme smallness of these valves, and narrowness of their seats, adapting them only for very short movements, will also be observed, the reason for which will be shown presently. For releasing the steam, one of these valves, of larger size, is employed at each end of the cylinder, which by a short travel opens a large area for this purpose. It works on the face of the cylinder, in a cavity or chamber formed in the underside of the steam-chest, and through which the steam passes, both in entering, and in escaping from, the cylinder.

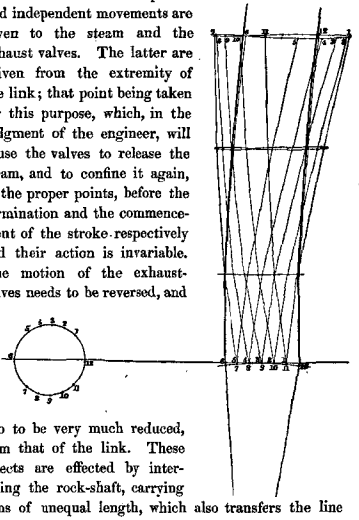
2. *The valve-gear.*—The movements of all the valves are derived from a single excentric, which is secured on the main shaft in the same position with the crank. The excentric operates a link which is rigidly attached to the excentric-strap, being formed, indeed, in the same piece of metal. The movements of this link are identical with those of the stationary link as ordinarily worked by two excentrics; the horizontal throw causes the sustaining-pin, on which the link is pivotted, to vibrate in an arc, the chord of which is equal to the throw of the excentric, and the vertical throw causes the link, while partaking of this vibratory motion, also to rock or tip about the said pivot. The engine represented in the plate is a stationary engine, not designed to be reversible,

but to run in the forward direction only, and, therefore, only the upper or forward end of the link is made use of. The advantage of this arrangement, over that usually employed for operating the stationary link, consists principally in its compactness, which is a feature of much consequence in this engine, as the space which the ordinary movements occupy is here required for others.

Care is taken that the motion of the sustaining-pin, or pivot of the link, shall coincide perfectly with that of the piston of the engine; the length of the line, connecting the centre of this pin with the centre of the excentric, being made to bear the same proportion to the throw of the excentric, that the length of the connecting-rod bears to the stroke or throw of the crank, so that the angular vibrations of the two are coincident.

The defect of opening the port at the crank end of the cylinder wider, and closing it later than the other, is remedied in this engine by dropping the sustaining-pin of the link a very small distance, so that the arc in which its centre vibrates, instead of springing from the centre line of the valve movement, and having this for its chord, will coincide with it at its middle, or highest point. The effect of this arrangement is to equalise the amount and duration of the openings made at the opposite ends of the cylinder, at every point of cut-off, up to the half stroke; beyond this point, the steam will follow the piston somewhat unequally. Stationary engines, which are not required to move their full resistance in starting, are constructed on this plan, in such a manner, that the steam cannot follow the piston beyond this point, and those engines which require the full pressure in the cylinder for a longer time when putting their load in motion, should cut off the steam at or before the half-stroke, after it has attained its momentum. The loop is also caused, by this arrangement, to approach more nearly to a single line, as shown in Fig. 2.

The effect of this depression of the sustaining-pin of the link is, that the link stands on the lead lines, not precisely when the crank is on its centres, but just before it has reached the inner centre, and just after it has passed the forward one; the centre of the excentric, which coincides in angular position with that of the crank-pin, standing then just so far below the centre line, as the centre of the sustaining-pin does. This occasions a slightly greater lead at the lower end of the cylinder than at the crank end, and it is a remarkable coincidence that this greater lead is required, owing to the greater velocity with which the piston travels in that end of the cylinder. Thus the same expedient, which gives in the opposite strokes steam-lines of equal length, gives also similar admission-lines and equal pressure, so that the indicator diagrams taken from the opposite ends of the cylinder are precisely the same. The movements of the link, as above described, are represented in the following diagram:



From the link separate and independent movements are given to the steam and the exhaust valves. The latter are driven from the extremity of the link; that point being taken for this purpose, which, in the judgment of the engineer, will cause the valves to release the steam, and to confine it again, at the proper points, before the termination and the commencement of the stroke respectively and their action is invariable. The motion of the exhaust-valves needs to be reversed, and also to be very much reduced, from that of the link. These objects are effected by interposing the rock-shaft, carrying arms of unequal length, which also transfers the line of motion from the centre of the link to the line of the valve-rod.

The valves for admitting and cutting off the steam are driven from the block, the position of which in the link is adjusted by the action of the governor, from that seen in the plate, at which the steam follows about one-half of the stroke, downward to the centre-line.

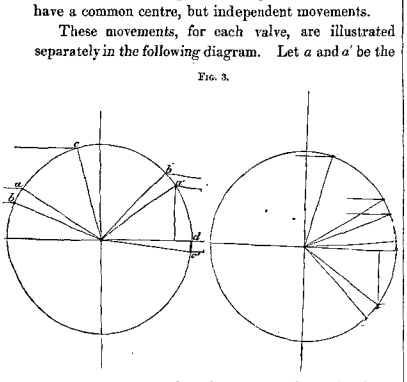
Between the link and these valves a movement is introduced of an important and interesting character. The objects effected by it are as follows: 1st. It causes each valve to open and close in the same time an area of port larger by 20 per cent., when cutting off at one-eighth of the stroke, and by 50 per cent., when cutting off at one-third, than it would if it was driven directly from the link. 2nd. At the same time it reduces the lap of the valve to one-third of that which it would otherwise have. This great reduction in the travel of the valve also enables valves to be used of only about one-half the size, while, the travel being reduced much more than the surface is, and the surface of the valve being made but little less than that of the seat, as will be observed, the wear is really diminished, and unequal wear is avoided.

The method by which these desirable results are effected in this engine is as follows: the induction-valve at either end of the cylinder is operated independently of the one at the other end, having a separate

stem and connections, quite up to the link. The two link-rods are connected with the block in the link by the same joint-pin, and therefore at this point their movements are identical. The movements of the valves, however, are always the reverse of each other, both in direction and amount, that of the one being accelerated in one direction, while that of the other is approaching a state of rest in the opposite one. Each valve is operated through the intervention of a rock-shaft, the driving and driven arms at the opposite ends of which are of equal length. One of these shafts is hollow, and the other passes through it, so that the two have a common centre, but independent movements.

These movements, for each valve, are illustrated separately in the following diagram. Let a and a' be the

FIG. 3.

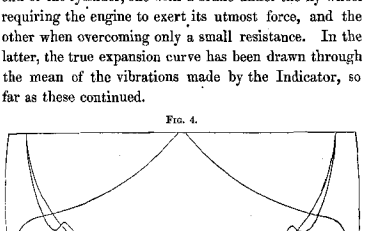


respective positions, when the crank of the engine is on its forward centre, of the driving and driven arms, through which motion is communicated to the induction-valve at the crank-end of the cylinder. These positions, it will be observed, are those of the crank and these arms, as represented in the plate. This valve has already uncovered its four passages, by the amount of the lead, and is nearly in equilibrium. The forward tipping of the link now causes the driving arm to vibrate toward its dead point, as far as the point b. Its motion in its arc at the point a is more rapid than that of the link, and becomes more and more accelerated as it approaches the point b, where it is reversed, and returns to the point a. The driven arm has imparted to it, of course, an equal motion, from a' to b' and back. These give to the valve its opening and closing movement, which is so much greater than the corresponding motion of the link, as the motion of the driving arm in the arc $a\ b$ is greater than it would receive if vibrating in the arc $a'\ b'$. This motion of the valve, though rapid and suddenly reversed, requires the exertion of scarcely any force. The driving arm now continues its return vibration to the point c, and the driven arm its corresponding one to the point c'. While thus the vibration of the driving arm becomes slower and slower as it rises from the point a, that of the driven arm, correspondingly retarded, reaches its dead point, and passes this a short distance, traversing fully the idle arc, and giving to the valve only a motion represented by the sum of the versed sines of the arcs $a'\ d$ and $d\ c'$, slightly increased by the angular vibration of the connecting link. It will be observed, that as the surface of the valve exposed to the upward balancing pressure of the steam becomes less, the motion of the valve grows slower, and the direction of its motion, at the extreme point of its lap, is reversed insensibly, as the driven arm is moved from its dead point.

By diminishing the angular distance between the arms, so that the driven arm would vibrate to a higher point than b', the opening and closing movement of the valve would be yet more increased, but this would involve a disproportionate increase in the lap. The movements of the arms through which the other valve is driven are precisely similar, and the relation of the two to each other can be readily observed on the plate and the diagrams. We have thus endeavoured to explain the nature of these valves and movements, which, with an expenditure of power altogether trifling, make every theoretical point in the working of steam, and that moreover at the highest speed of piston that is employed in the locomotive.

The following diagrams, taken from the engine running in the International Exhibition, non-condensing, 24″ stroke, at 140 and 150 revolutions per minute, illustrate this action. Two diagrams were taken from each end of the cylinder, one with a brake under the fly-wheel requiring the engine to exert its utmost force, and the other when overcoming only a small resistance. In the latter, the true expansion curve has been drawn through the mean of the vibrations made by the Indicator, so far as these continued.

FIG. 4.



These valves and movements are peculiarly adapted for high velocity, and the engine has been especially designed with reference to the employment of very rapid speed of piston; and it is in this view that the principles of its construction claim attention.

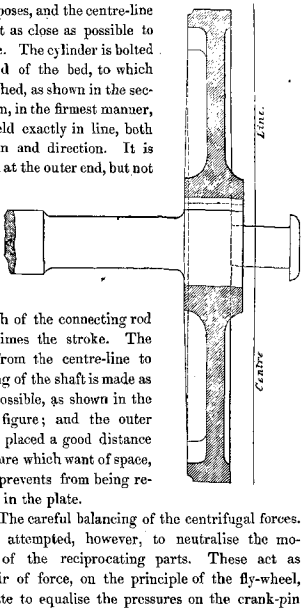
It is a horizontal engine. With a beam engine high speed is impracticable: it is the self-contained, direct-acting engine only, in which it is possible to employ rapid movements with success, and for stationary purposes the builders of this engine regard the hori-

zontal as the best form. In this engine it is attempted to derive from the horizontal form, in a greater degree than has yet been done, the advantages which it is really able to give; and for this purpose these engines are caused to make from 150 revolutions per minute with 24″ stroke, to 125 revolutions with 36″ stroke, giving a velocity of piston of from 600′ to 750′ per minute; and their designer claims that they will run at this speed, under any required pressure of steam, exerting their full power, in entire silence, without any vibration, and with no greater wear in the brasses, bearings, cylinder and valves than is found in the best vertical engines, which work under more than a nominal pressure, that there will not be any wear at all in the valve-gear, and that they will require no more than ordinary care.

These results are due to the following causes:—

1st. The general construction, by which the direct strains are most perfectly resisted, and indirect ones are reduced to a minimum. The form of the bed, it will be observed, is well adapted to these purposes, and the centre-line is brought as close as possible to its surface. The cylinder is bolted to the end of the bed, to which it is attached, as shown in the sectional plan, in the firmest manner, and is held exactly in line, both in position and direction. It is supported at the outer end, but not confined, so that it can expand and contract freely.

Fig. 5.

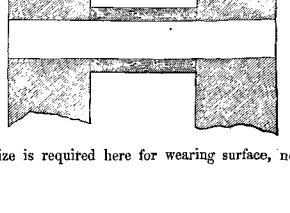


The length of the connecting rod is three times the stroke. The distance from the centre-line to the bearing of the shaft is made as short as possible, as shown in the following figure; and the outer bearing is placed a good distance off, a feature which want of space, however, prevents from being represented in the plate.

2nd. The careful balancing of the centrifugal forces. It is not attempted, however, to neutralise the momentum of the reciprocating parts. These act as a reservoir of force, on the principle of the fly-wheel, and operate to equalise the pressures on the crank-pin at the opposite ends of the stroke. The diagram described by the Indicator represents the pressure of steam on the piston; approaching in this engine during the first part of the stroke, and up to the point of cut-off, nearly to that in the boiler, then falling as the steam expands, until, at the termination, it is generally in a non-condensing engine nothing above the counter-pressure of the atmosphere, and in a condensing engine perhaps one-fourth or one-sixth of that at the commencement. But this diagram does not represent correctly the force exerted on the crank-pin. At the commencement of the stroke the reciprocating parts are at rest. At a point near the middle they are moving with a velocity equal to that of the crank-pin, and the power absorbed in giving to them this amount of motion in this interval of time, is not yet transmitted to the latter. But they must be brought to a state of rest again at the termination of the stroke. This is done by the action of the crank, and now gradually they impart to it the force which was at first absorbed, or, as it were, withheld. By so much, therefore, the pressure on the crank-pin is less near the commencement, and greater toward the termination of the stroke, than that on the piston, as represented by the diagram. This operation becomes important at high velocities. Let, for example, an engine be making 25 revolutions per minute, and let a represent the velocity imparted to the reciprocating parts, and t the time occupied in imparting it. Let now the same engine be caused to make 150 revolutions per minute, the velocity imparted to the reciprocating parts is now $6\,a$, and the time occupied is $\frac{t}{6}$, or this velocity of $6\,a$ is imparted to these parts six times in the time t. Therefore, in the latter case, thirty-six times the amount of power is absorbed in this manner at the commencement, and given out at the termination of the stroke, that there was in the former, and we find that this action varies as the square of the velocity.

3rd. The employment of extended wearing surfaces, in the piston, the cross-head, the connecting-rod ends, and the main shaft bearings. The latter, in an engine of the size represented, are 4·5″ in diameter by 12″ long, and the cross-head has a surface of 70 square inches. Mere extent of surface, however, is of little value, unless we have also truth of form, and a surface of such a nature that this will be permanently maintained. A perfectly cylindrical form is equally important and difficult to be obtained. The construction of the cross-head pin is shown in Fig. 6:—

Fig. 6.



Size is required here for wearing surface, not for

strength, and the difficulty to be overcome is the tendency for this pin to wear flat on its opposite sides, the pressure being there entirely, and the frictional motion continually changing its direction, whereby a greater wear is produced than would be by a much more rapid motion in one direction. A cast-steel ferule is made and hardened. The hole is then ground out quite true, and the surface afterwards brought up to a cylindrical form by grinding with an emery wheel in the following manner:—The piece revolves in a lathe, the emery wheel revolves at a rapid speed in contact with it, and is caused at the same time to travel back and forth in a line parallel with its axis. The cross-head is then bored, and the holes carefully finished to a size; on one side a trifle larger, and on the other side smaller, than that in the ferule. To these an unhardened steel pin is then carefully fitted, and forced into its place by strong pressure. The crank-pin and necks of the main shaft have also hardened surfaces, made cylindrical by the same process.

4th. The construction of the joints in the valve gear. These consist of hardened pins, the surfaces of which are finished in the manner above described, turning in hardened steel bushings, ground out to the proper fit. Though there are a number of these joints, still it is to be observed that the labour on each one is trifling, and the construction such that no lost time can arise in them, even with very long use, and the movements of the valves cannot be deranged.

The cylinder in this engine is protected from the refrigerative effect of the current of exhaust steam over its external surface, by interposing the chamber seen in section in Figs. 4 and 5, which is filled with any suitable non-conducting material. High speed conduces to diminish the loss of heat internally; because a given quantity of steam, employed in a given time, to exert a given power, cools (as its temperature falls by expansion and release or condensation) a less surface, as the speed is increased, and consequently a smaller cylinder is used; the intervals of alternate cooling and warming are shorter and more numerous; the aggregate time during which the cylinder is exposed to the cooling vapour remains the same, but the extent of surface to be kept at a certain temperature against a certain refrigerative influence, diminishes as the speed is increased. A moderate superheating of the steam, perhaps to a temperature ten or twenty degrees above that which is due to the pressure, is recommended also, as being (in connection with the rapid speed, which allows the cool vapour to abstract the heat from the cylinder only during a very brief interval) the most efficient means for keeping the temperature of the metal above the point at which it will begin to condense the entering steam.

Porter's Improved Governor is employed on this engine to regulate the speed, by changing the point of the link from which the induction-valves are driven. No other form of governor was found able to adjust the position of the block in the link with sufficient accuracy, to maintain that uniformity of motion, under sudden and extreme changes of resistance, which is required in this engine. This governor presents a singular combination of sensibility and steadiness, and the philosophy of its action is deserving of attention, and is set forth by the inventor as follows:—It will be seen, by reference to the plate, that the balls in this governor are very small, and swing from a single joint. They make from 300 to 350 revolutions per minute, and the centrifugal force, developed by this rapid velocity, sustains a counterpoise of from 15 to 20 times their own weight. This counterpoise forms a part of the slide, and is so connected with the balls as to have nearly twice their vertical movement. The governor obeys the law of the pendulum, and the motion of the slide is, of course, the same which any one should have, that is connected in a similar manner, to a conical pendulum of the same altitude, having a fixed apex.

Theoretically a governor should be infinitely sensitive; that is, an infinitely small change in the velocity of its revolution should be attended by a simultaneous corresponding change in the position of the balls. Nothing but friction prevents this degree of sensibility from being exhibited in the action of any governor. The balls are usually driven through the joint or joints from which they swing. While the motion continues constant, they revolve in a plane, in which their centrifugal force and their gravity are in equilibrium. On a change of speed, this equilibrium is disturbed, and then the excess of one of these forces over the other would cause the balls to rise or fall to another plane of revolution. But on a slight variation of speed, this development of force to produce motion is exceedingly small; and at the same instant there arises, from the resistance to change of motion opposed by the inertia of the balls, a friction in the joints through which they are impelled, far greater than this slight force can overcome. The governor remains therefore without action, until either the pressure in the joints is relieved, or the change of speed has become so considerable that the preponderance of one of the counteracting forces is sufficient to overcome the friction caused by it. The action of the governor is also generally more or less hindered by resistances in the valve or the cut-off gear, but the difficulty above described is the principal cause of its sluggishness. It often happens, also, as a consequence of moving too late, that when the governor does move it moves too far, and produces an oscillating motion of the engine, alternately too fast and too slow. To meet these difficulties, the first expedient has been the employment of heavy balls; but this has proved insufficient, for the obvious reason, that the inertia to produce friction increases precisely as the gravity, and moreover the centre of gyration of the larger masses is commonly

further from the axis. A yoke is also often employed, for the purpose of applying the pressure, to accelerate or retard the motion of the balls, at points on their arms as far from the axis as possible; but this again is of little advantage, because while by this arrangement the inertia of the balls has less power to produce friction, the preponderant force has also just as much less power for overcoming it. The tendency to oscillation has generally been prevented by destroying the sensibility of the governor. This is done by making the balls to swing from independent joints, on opposite sides of the spindle, and which are sometimes placed several inches apart. The apex of the cone described by the revolution of the governor is, in this construction, found at a point where the centre lines of the two arms will intersect, if produced upward, and the altitude of the cone must be measured to this point from the plane in which the balls revolve. As the balls rise or fall, the cone is shortened or lengthened at both ends, and sometimes the apex moves several times further than the base. As the variations of speed of the engine must correspond with the changes in the altitude of the conical pendulum, it will be understood at what great cost the tendency to oscillate has been prevented.

In this governor the difficulties above described have been surmounted, in the manner which will now be explained, and an action is attained which seems quite unhindered, even when overcoming some amount of resistance. Obviously, the first requirement is, that, on a small change of speed, a considerable force shall be developed, to produce motion; and the second is, that the least possible amount of friction shall arise to retard it. The force can be had only by employing strong forces in counter-action. The centrifugal force in this governor is obtained by revolving the small balls at a high velocity, this force increasing as the square of the speed. It will sustain a weight equal to that of the balls, and moving through the same vertical distance, for each time the force necessary to sustain the balls themselves is exerted. Thus if 50 revolutions per minute will develop force to sustain the balls in a given plane of revolution, then 300 revolutions will develop force to sustain 36 times their weight, or 18 times moving through twice the distance, as the counterpoise in this governor does very nearly.

Thus force is provided in abundance, but how about the friction, at the instant when the great velocity of this heavy mass is checked or accelerated? for it must be borne in mind, that if it revolves six times as rapidly, then, on any given change of speed in the engine, its motion must be retarded or increased six times as much. The centre of gyration of the balls and counterpoise together will be, in the largest sizes of these governors, about two inches from the axis; the joint from which they are driven is six inches in length, and is of the peculiar construction shown in the plate, so that the action impelling them is equal through each arm. The pressure for this purpose is distributed over four inches of length of the pin, and its mean point is two inches from the axis, the same distance as the centre of gyration, and therefore moving with the same speed. The pressure on the joint pin, arising on any change of speed, is consequently only the same in amount that would require to be exerted, if the same weight, in the form of ordinary balls, should be impelled by force applied at their centres. Moreover, this pressure against the surface of the pin is in directions at right angles to its axis, and the resistance which it opposes to the free action of the governor, must be considered as exerted at the ends of the very short levers, whose length is half the diameter of the pin, about $\frac{1}{4}$ of an inch, and it varies directly as the velocity. But the force developed to produce motion varies as the square of the velocity, and, moreover, if the speed be accelerated, it is exerted at the centres of the balls, 18 inches from the axis of the pin, or at the ends of levers 72 times as long, and if the speed be retarded, it is applied at the ends of the lower arms, or at the ends of levers 144 times as long as those at the extremities of which the resistance is exerted. Thus the combination of the rapid velocity, the central counterpoise, and the long joint, gives to this governor its great sensibility. Its action demonstrates also, that the highest steadiness or stability is attained by the free counter-action of strong opposing forces.

CLIFTON SUSPENSION BRIDGE.

Plates 31, 32, and 33.

THE work which forms the subject of this article is the completion of the suspension bridge over the river Avon at Clifton, near Bristol, by an adaptation of the chains lately taken down from the Hungerford Suspension Bridge over the Thames at London. This latter bridge was designed only for foot passengers, and was purchased by the Charing Cross Railway Company, in order to give place to a railway girder bridge

forming their approach to the Charing Cross terminal station.

The engineers are Mr. Hawkshaw and Mr. W. H. Barlow, and the cause of there being two engineers is somewhat amusing. Upon the purchase of the Hungerford bridge for the purpose of its conversion and the consequent removal of the chains, the idea of adapting them to the Clifton bridge occurred to both these gentlemen, and Mr. Hawkshaw agreed for the purchase of the chains from the Railway Company, whilst Mr. Barlow was similarly occupied at Clifton in the purchase of the piers and land and approaches from the trustees of the Clifton bridge. Each gentleman being ignorant of the others movements, then reversed positions, and found himself forestalled, it was accordingly determined to carry on the work conjointly.

The Clifton bridge was commenced in 1830, and progressed as far as the completion of one approach and a considerable advancement of the other, together with the completion of the piers, and the preparation for the anchorage of the chains. At this point the funds (which consisted of subscriptions from persons residing in Bristol and its neighbourhood, added to a sum of money bequeathed by a Mr. William Vick nearly a century before) failed, and the piers have reared their heads from that time to this on either cliff as evidences of a noble design inadequately supported. The estimate for the completion of the work, as made originally by Mr. Telford, and confirmed by the late Mr. Brunel, who furnished the designs from which the approaches and towers were executed, was £52,000, and the money expended on the work was £45,000. Under these circumstances it appears strange that the balance necessary to complete the works should not have been procurable, seeing that the bridge is one of great importance to the surrounding district, forming as it does a communication between the counties of Gloucester and Somerset, and avoiding the necessity, to all persons residing on the high ground around Clifton, and wishing to cross the river, of taking a circuitous route through Bristol, and descending to and ascending from the bottom of the gorge.

The two bridges (Hungerford and Clifton) being of different dimensions, and adapted for different purposes, the one having been for foot passengers only, whilst the other will afford accommodation for a double carriage way and a double footway, it is fortunate for those interested in the completion of the larger of the works (the Clifton bridge) that the superstructure of a suspension bridge is capable of a conversion and transposition, which no other description of bridge can equal, and we will, therefore, exhibit the two bridges in contrast in most of their important features. But first we will mention a characteristic in which they will be similar, but will differ from almost all chain suspension bridges heretofore constructed. In the Hammersmith, the Menai, the Friebourg, and most, if not all, previous suspension bridges and piers, the number of plates in each succeeding link have been the same, which has involved the necessity of having coupling links, and consequently doubling the number of joints; whereas the links as adopted at Clifton, and as arranged formerly at Hungerford, differ alternately by one, being alternately eleven and twelve near the centre of the bridge, and twelve and thirteen near the piers. By this arrangement the ends of the plates are united directly to one another, and much labour and expense is avoided.

In the above respect the arrangement in the two bridges are similar; in most others they must necessarily differ more or less, as we shall proceed to show.

In the Hungerford bridge the chains were four in number, arranged in pairs one above the other, and, as the joints of one chain were made to come over the middle of the other, the distance between the suspension rods was nearly half the length of the link, and the rods were attached to the centre of a cross-head, one end of which was suspended from the bolt of the joint, whilst the other was connected to a bar passing transversely across the centre of the link of the other chain. In the Clifton bridge the chains will be three in number, instead of two, and as they will be placed one above the other, and break joint at equal distances, the distance of the suspension rods from one another will be about the third instead of the half of the length of the link, and the suspension will be direct from each joint. Any tendency to unequal strain on either of the chains will be avoided by the rigidity of the lattice longitudinal girders to which the cross girders are attached, and which will spread any weight which could possibly come upon the bridge over a span of several links. These lattice girders, to the top of which the suspension rods are attached, and from the bottom of which the cross girders, which support the carriage road and footpaths are suspended, is also a new feature in the bridge. The principle was proposed several years back by Mr. Peter Barlow, and has been more recently carried out in the United States, and in the Lambeth bridge lately erected by him.*

The following Table will exhibit the principal dimensions of the two bridges:—

		Hungerford.	Clifton.
Height of piers above mean water ...	ft.	80 ...	257
Centre span between piers	ft.	676½ ...	702¼
Deflection of chains		50 ...	70
Length of each link	ft.	24 ...	24
Weight of each link	cwt.	5¾ ...	5¾
Diameter of connecting pins	ins.	4⅞ ...	4⅞
Whole number of links		2,600 ...	3,636
Total weight of links	tons	715 ...	1,000
Number of links in centre span	...	1,280 ...	1,981
Weight of links in centre span	tons	352 ...	544

* See Record of Modern Engineering, article "Lambeth Bridge," page 42. Plates 26, 27, 28, and 29.

	Hungerford.	Clifton.
Width of platform ... ... ft.	14 ...	31
Section of chains at centre of centre span, sq. in.	296 ...	440
Ditto near the piers ... ... sq. in.	312 ...	481
The comparative loads will be as follows :—		
Maximum load at 70 lb. per square foot tons	296 ...	814
Strain due to weight of chains ... ... tons	620 ...	680
Ditto to weight of platform and roadway tons	99 ...	543
	1,015	2,037
Strain in tons per sq. in. of section of chains, tons	3·43 ...	4·23
Strength of chains allowing 17 tons tensile strain to the superficial inch of section ... tons	5,032 ...	7,480
Cost	£80,000 ...	£72,000*

The towers, approaches, land, &c., were purchased for £2,000, and the chains for £6,000.

It will only now be necessary to refer to the drawings :—

Plate No. 31 exhibits an elevation of the bridge, and a cross section of the platform. Regarding the former no remarks are necessary. The platform consists of a centre opening, 20 ft. wide between the suspension rods, and having an available roadway of 16 ft. 8. in., and two side openings of 5 ft. 6 in. each from the suspension rods to the hand-rail, and giving an available width of footpath to each of 5 ft. 2 in. The fence on either side between the carriage road and the footpaths, which forms the points of suspension, and also the outer parapets, consist of lattice girders, those on either side of the carriage road being directly attached to the suspension rods. All four of these act as stiffening longitudinal girders. The elevation of them will be found in Plate 33.

The sectional area of the upper rib of the suspension girder is $13\frac{1}{4}$ in. and the section of the lower rib $12\frac{3}{4}$ in., and the depth of the girder is 5 ft. This depth is latticed with $2'' \times 3\frac{3}{8}''$ bar iron spaced at $10\frac{1}{2}$ in., and stiffened with **U** iron uprights 2′ 8″ apart, every third one having a leg stepping back 15 in. towards the roadway, and protecting the water table. Now, as the suspension rods are about 7′ 6″ apart, and the three chains breaking joint with each other, the suspension rods from the extreme ends of each plate will be 22′ 6″ apart, and a girder of this dimension is capable of bearing a load of 170 tons, so that any load which the bridge can ever have to carry must be spread over a considerable space. The hand-rail also, from its being attached to the end of each of the cross girders, by means of the cast-iron standards, will add to the stiffness of the floor by dispersing the load. The cross girders are on a somewhat similar design to those adopted in the new railway bridge at Hungerford, being rivetted on to the bottom of the stiffening girders from which they are suspended, and projecting on either side of the roadway to carry the footpaths. Each end is suspended by four $\frac{7}{8}$ in. rivets. This girder has a length of 20 ft. between the points of suspension, and a depth at the centre of 1 ft. 6 in., with a top and bottom rib of $4\frac{1}{2}$ in. area, and are capable of carrying a load of 22 tons each, whereas its load can never be more than 8 tons. The flooring of the roadway is perhaps the simplest which has ever been adopted for such a purpose, being merely half baulks laid longitudinally to the bridge, with close joints and tongued with hoop-iron about half-way through its thickness. The under side of the carriage way is latticed horizontally from the ends of every alternate cross girder by wrought-iron braces. These cross one another in the centre of the intermediate girder to which they are bolted. See Fig. 1, Plate 33.

The saddles to which the chains are attached at the summits of the piers are shown in elevation and section in Plate 33, Figs. 4 and 5. The saddles which were used at Hungerford were, of course, adapted for two chains, and are shown by the unetched portion of Fig. 4. They consist of a series of flat plates of wrought iron placed vertically, side by side, with intervals corresponding to the number of the bars in the chains.

The plates are kept in position by a centre pin, 3 in. diameter, which passes through the centre of the whole of them. The intervals are 1 in. wide, being just sufficient to admit the ends of the bars which are $1\frac{1}{8}$th thick. As a third chain is added for the Clifton bridge, an addition has been made of an upper or crown saddle, which rests on the top of the old saddle, and is held in its place by the check pieces shown in section, Fig. 5. A lower base plate has also been added to the old design.

The entire saddle rests on a roller frame containing fifty rollers, and has a capacity of motion of 1′ 6″ in each direction. The rollers are arranged in two rows, with a strong wrought-iron bar between them, and each row is arranged in five sets of five rollers in each, and having a tie-bar going through from side to side between each set, and also at the extreme ends. The bolts which attach the chains to the saddle are of the same diameter as the coupling bolts, namely, $4\frac{3}{8}''$.

The mode of anchorage is shown in Plate 32. The chains, after passing over the heads of the towers, are carried down again at the same angle to the surface of the ground, which they strike at 180 ft. from the centre of the tower. From this point galleries are sunk at a rather more acute angle to the tower than the angle of the chain. At the top of each gallery, the rock is levelled down to receive a saddle, to which the chains are attached, and by means of which the direction of the chains is altered, and all vibration prevented by the pressure which is brought to bear upon the saddle. The gallery is 70 ft. in length, and enlarges as it descends,

* This amount is made up as follows :—

Amount originally expended	£45,000
Amount expended on completion, including refixing, carriage, and supplying all materials and additional chains, but exclusive of the price paid to the Bridge Commissioners for the towers, and to the Charing Cross Company for the chains	£27,000
	£72,000

To this must be added the remuneration to the Engineers.

the last 15 ft. being bevilled on the top and bottom, and the sides worked into skewbacks, from which a mass of arched masonry is built from side to side. On the crown of this inverted arch, a flat bed is built to receive the cast-iron bed plates. These plates are cellular, having a flat bed of 6′ 0″ × 5′ 0″, and a depth of 1′ 6″; at the centre of the plates twelve slits are cast, each 1 in. wide, and 1′ 1″ long, through which the twelve plates of the chain pass, and are secured by folding wedges on the under side. A wrought-iron washer, perforated similarly to the bed plate, is placed between it and the wedges. The wedges are formed of steel, and are each 4′ 6″ long; they are bevilled from 4″ × 6″ at one end, and 4″ × 3″ at the other. Access is obtained to the anchorage by means of shafts of upwards of 50 ft. in depth.

METROPOLITAN (UNDERGROUND) RAILWAY.

Plates 34, 35, and 36.

In accordance with a promise made to our subscribers at the commencement of the year, we give this month three plates, illustrating some of the chief features of interest in the Metropolitan Railway.

Some years back the late Mr. Charles Pearson devoted much time and labour, and no small outlay, in trying to convince the public that a central station at Farringdon-street, to be connected with all the great metropolitan termini, was feasible and advisable. However, all his efforts were unavailing; and had he lived to see his project thus far carried out, he would have been obliged to confess that his idea of concentrating all the traffic in the heart of London was fallacious, and that the great desideratum which it is now hoped to effect, by traversing the town with railways, is, to relieve the streets of the enormous traffic which has increased so rapidly in the heart of London within the last few years. The Underground Railway is the first link in this system. It was commenced about four years back, and was completed and opened for traffic on the 10th January last. The whole length is about 3½ miles. Commencing by a junction with the Great Western Railway at Westbourne Place, Paddington, on a level with that railway, it proceeds in an easterly direction to the South Wharf Road, which it traverses, and passing under the Edgware Road at right angles, and under Burn Street and Upper Lisson Street, strikes the Marylebone Road at the end of Stafford Street; from thence it passes along the centre of the Marylebone Road as far as the Crescent, at the top of Portland Place. Passing under the houses at the eastern extremity of Park Crescent, it traverses the centre of the Euston Road to King's Cross. Here it forms a junction with the up and down lines of the Great Northern Railway, and turning to the south, passes under the Bagnigge Wells Roads, skirts Guildford Place, and passing under Coppice Row near its junction with the new Farringdon Road, terminates at a station at Cow Cross. Up to King's Cross the line is in tunnel, but here open cutting commences, and, with the exception of about 600 yards of covered way beneath Bagnigge Wells Road and Coppice Row, continues to the station in Farringdon Road. From this point the line is proposed to be continued to the north of Smithfield and to the south of Charterhouse Square, and through Barbican to the neighbourhood of Finsbury Circus. Another branch will intersect Skinner Street, and join the London, Chatham, and Dover Railway at their station on the site of the old Fleet Prison. The steepest gradient on the line is 1 in 100, and the average slope from west to east is 1 in 300. The sharpest curve is 200 yards radius. Throughout the whole length there is not more than 1,200 yards of straight line.

In some portions of the line the crown of the arch is only a few feet below the surface of the ground, but at others the depth becomes much greater, the rails being sometimes at a depth of 54 feet. No general description can be given of the works, which required to be adapted to the great varieties of subsoil through which they had to pass, consisting of gravel, clay, rubbish, and sand, much of which had been weakened by excavations for and filtration from sewers and gas and water-pipes.

Any one conversant with the superintendence of large works of a similar character will readily give all praise to Mr. T. Marr Johnson, the Resident Engineer, for the incessant anxiety and watchfulness which the charge of such a work must have cost him. A whole volume would not be sufficient to give a detailed account of the contrivances adopted and the difficulties met with at various parts of this work, and we regret that the nature of this publication obliges us to select so few examples, although those few will go far to illustrate the complicated nature of the designs.

There are seven stations on the line—viz., Paddington, Edgware Road, Baker Street, Portland Road,

Gower Street, King's Cross, and Farringdon Road. Five of these stations have roofs open to the air; the two exceptions are those at Baker Street and Gower Street, both of which being immediately beneath the road, are necessarily arched, and are approached, lighted, and ventilated from the sides. The arrangements for effecting the two last of these objects will principally form the subject of our illustrations, and will furnish examples of great ingenuity and boldness of design.

Plate 34 contains sections of the tunnels between the Stations on the main line, both with and without an invert; it is an elliptical arch of 28 ft. 6 in. major axis, and with a rise of 11 ft. This is the form which has been generally adopted, but there are a few places where the rise has been slightly increased to meet increased vertical pressure. In like manner the foundations have in several cases been carried lower than they are shown in Fig. 3, which merely indicates the minimum which would be allowed.

It may be necessary to state, for the information of those subscribers who are not acquainted with the locality, that the Marylebone and Euston Roads, along which this tunnelled way is carried, consists of a broad road, with footpaths on either side, flanked by gardens running up to the fronts of the houses on either side, and in these localities the ground at the back of the abutments has been but little disturbed. This, however, was not the case between the Marylebone Road and the Great Western Railway Station.

Plate 34 also shows the section of the tunnels which connect the Main Line with the Great Northern Railway at King's Cross. Both of these sections are provided with recesses for the protection of the workmen, and for the depositing of tools. This plate does not require any detailed explanation.

Plates 35 and 36 show the manner of constructing the Stations at Baker and Gower Street. The line at these Stations runs immediately down the centre of the main road, and the approaches and Stations for the up and down platforms are built in the gardens to the north and south of the road. They are sunk to the level of the platforms, and have one suite of offices below, and one above the level of the road. The platforms on either side are 235 ft. in length by 10 ft. in width, and are lighted entirely by perforations made through the springings of the arch as shown in Fig. 1, Plate 36, and Figs. 1 and 2, Plate 35. The arch which spans the line and platforms is a segment of a circle of 32 ft. radius, having a chord of 45 ft., and a versed line of 9 ft. The abutments from which this arch springs are shown in section and elevation in Figs. 1 and 2, Plate 36, and may be said to be composed of so many piers 3 ft. 9 in. wide on the face towards the line, and 5 ft. 6 in. in depth. The back of each pier is reduced to 2 ft. in width, which allows of skewbacks being formed on either side, from which arched retaining walls are built across. These piers and retaining walls stand on an 18 in. bed of concrete, and are backed with concrete to a level with the back of the piers. A 9 in. wall is built in front from pier to pier, leaving a hollow between the two walls. At eight of these recesses on either side, the arch is perforated by an opening, arched at the top and bottom, and flat at the sides, 10 ft. high by 4 ft. 9 in. wide, and reducing at the outer extremity to 6 ft. high by 4 ft. 9 in. wide. These orifices open into an area, the top of which is partly covered with glass and partly with gratings to allow for ventilation. The back of this area is inclined at an angle of 45°, and together with the interior surface of the lighting and ventilating galleries, is lined with white glazed porcelain tiles. The reflected light from these tiles is very powerful, and during the daytime no gas is required. The archway of the Main Line is 10 rings of brickwork in thickness at the springing, and the arch at the top of each orifice which pierces it, is 7 rings thick, and is ramped back in steps of 2 courses each, see Fig. 1, Plate 35. This description does not apply to the openings which are rendered necessary at the Stations for the several doorways leading to offices and staircases. Here the ground at the back of the abutment was excavated for the purpose of erecting the building, and the arch has therefore no support but the party walls which form the continuation of the piers, and here therefore the arch of the perforation has been lined and shod with iron castings, as shown in the various cross sections, elevations, and plans, Figs. 3 to 12, Plate 36. The design of this bracing will be best seen in Fig. 4, which is a section through the centre of the larger arch in the elevation of relieving arches, Fig. 3. The lower part of the shoe, as shown in Fig. 4, is built into the top of the pier as shown in front elevation, Fig. 6, and the upper part is built into the party wall, and firmly compressed by the arched roofs of the rooms and passages, and as the feet of the skew arches are bolted together, the whole is thus connected from end to end. Figs. 9, 10, 11, and 12 show the form of the castings, slightly modified for the terminations at either end.

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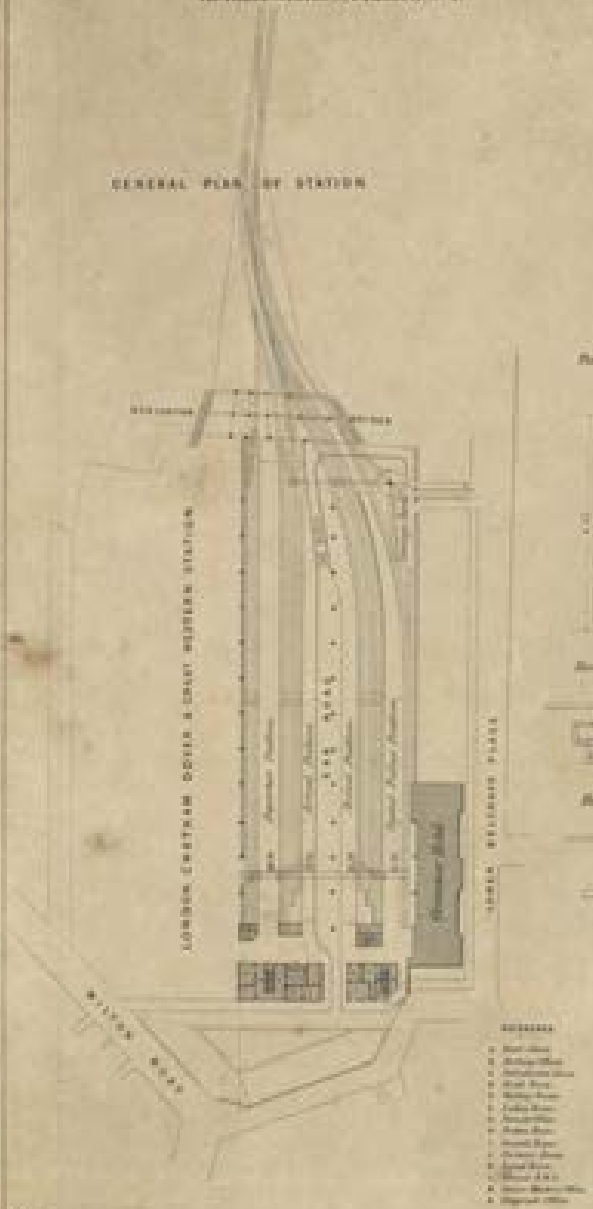
LONDON BRIGHTON AND SOUTH COAST RAILWAY.

VICTORIA STATION, PIMLICO Nº 1.

A REVIEW OF THE PROGRESS OF MODERN ENGINEERING.

PLATE I.

GENERAL PLAN OF STATION

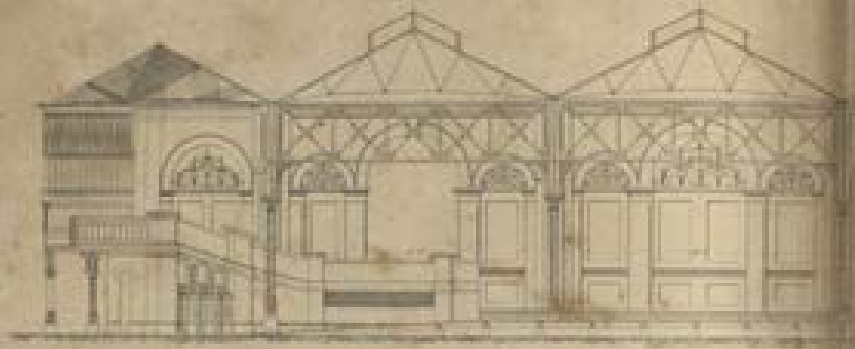

LONDON CHATHAM DOVER & SOUTH WESTERN STATION
LONDON BRIGHTON & SOUTH COAST STATION
Victoria Road
Victoria Station
Victoria Road
Victoria Station
Victoria Road
Victoria Station

LONDON BRIGHTON AND SOUTH COAST RAILWAY.

VICTORIA STATION, PIMLICO, 1862.

LONGITUDINAL AND TRANSVERSE SECTIONS

PART LONGITUDINAL SECTION ON LINE A.A. ON PLAN



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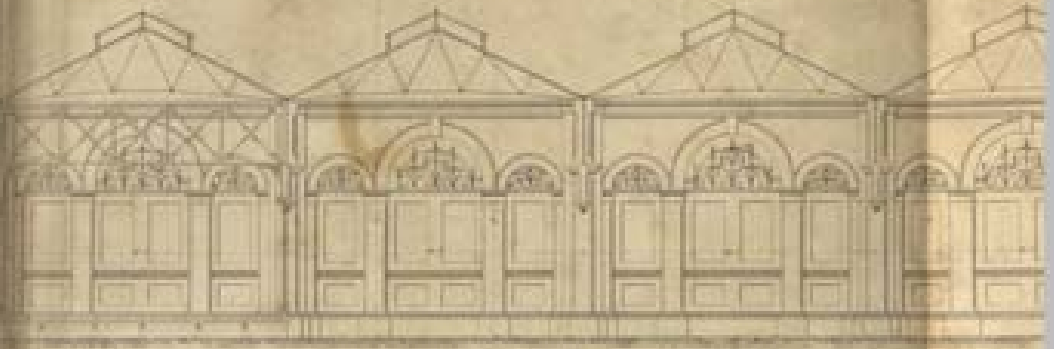
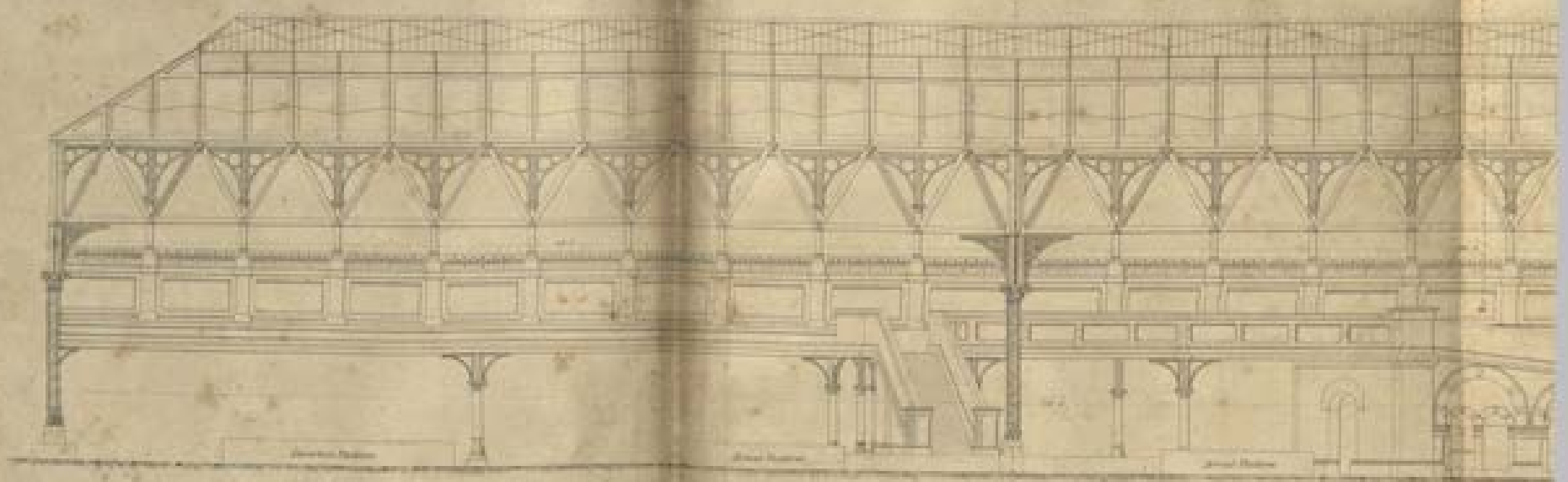
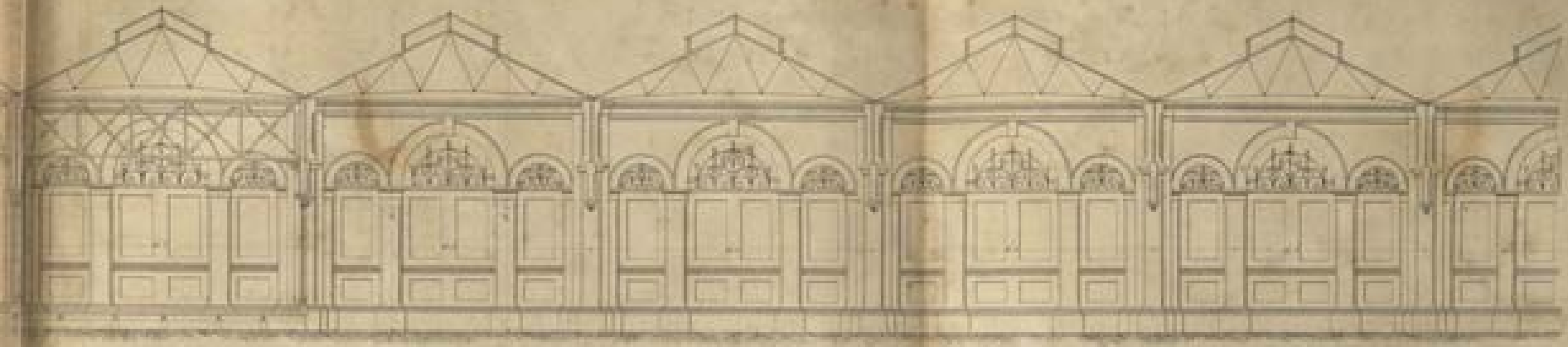


TRANSVERSE SECTION OF STATION SHOWING SCREEN AT ECCLESTON BRIDGE

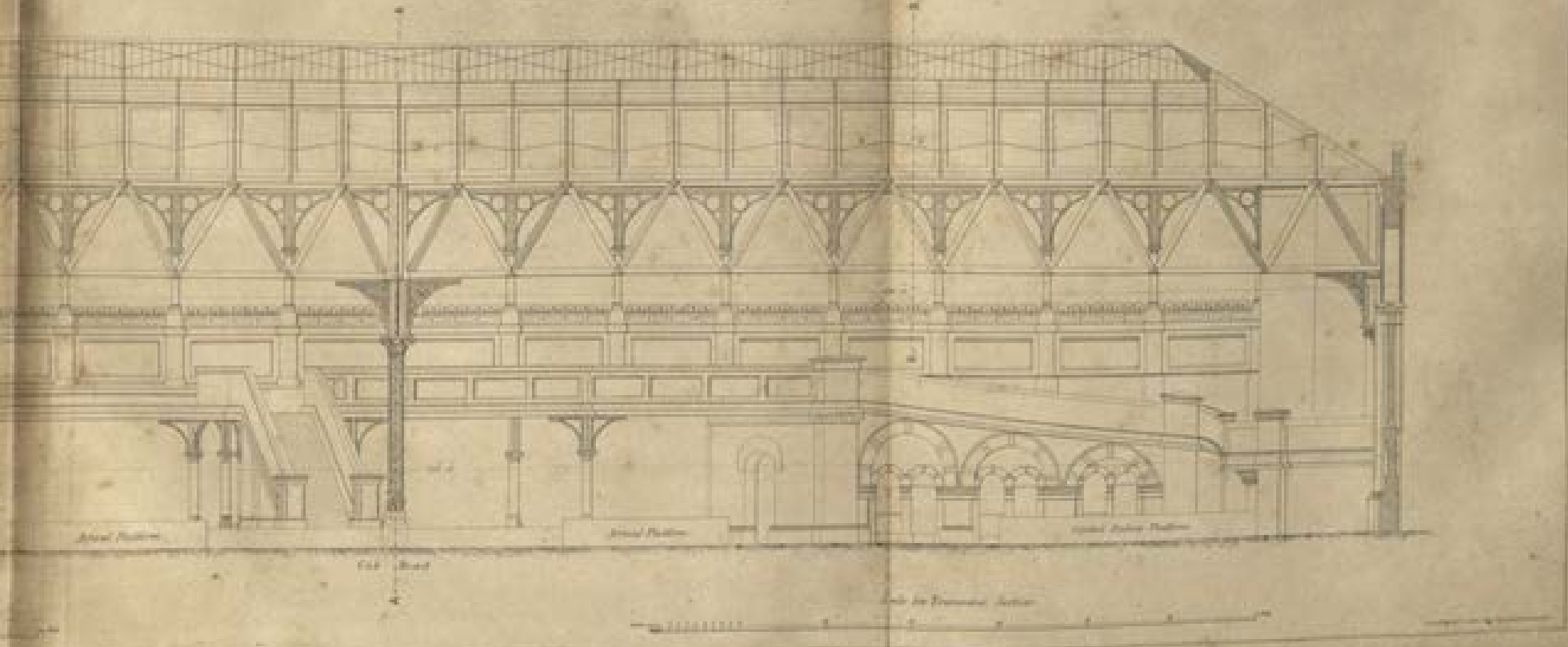


LONGITUDINAL AND TRANSVERSE SECTIONS

PART LONGITUDINAL SECTION ON LINE BB ON PLAN



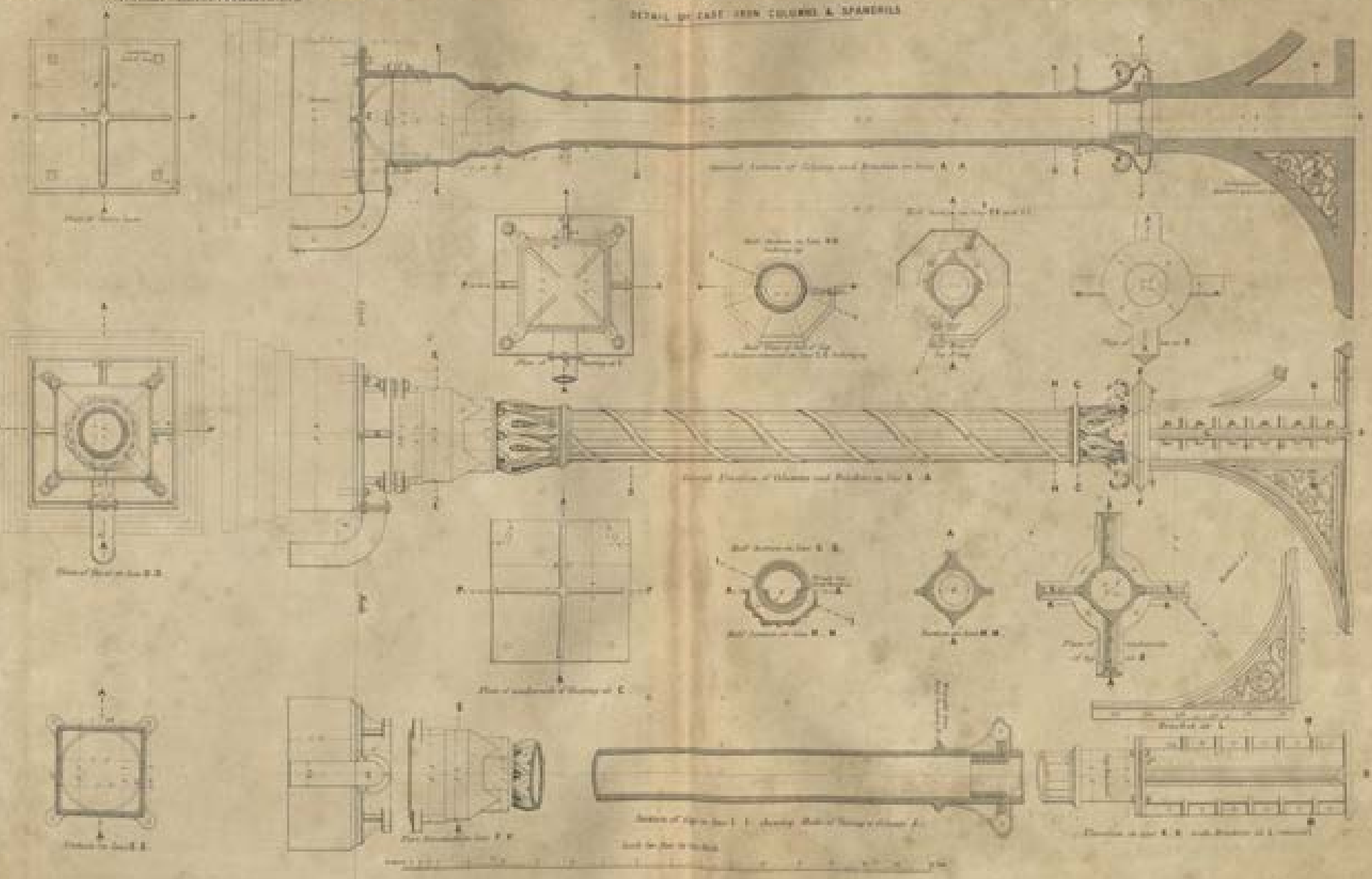
TRANSVERSE SECTION OF STATION SHOWING SCREEN AT ECCLESTON BRIDGE



LONDON BRIGHTON AND SOUTH COAST RAILWAY.

VICTORIA STATION. PUBLICO. No 2.

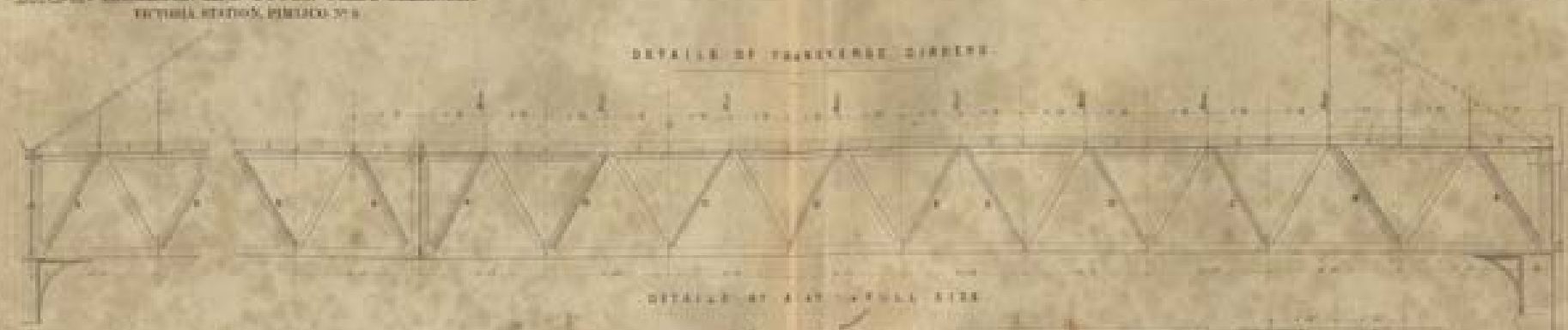
DETAILS OF CAST IRON COLUMNS & SPANDRILS



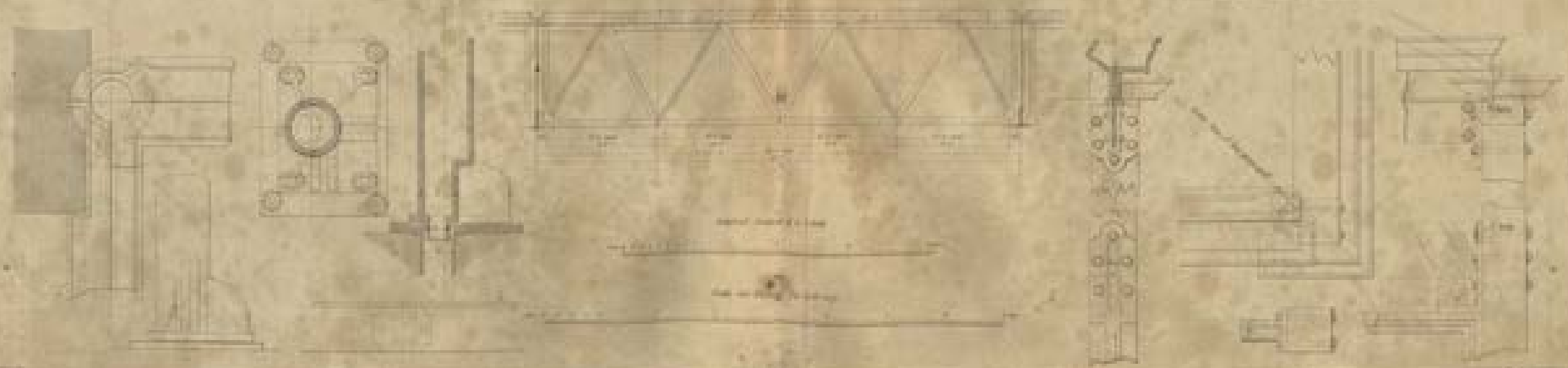
LONDON BRIGHTON AND SOUTH COAST RAILWAY.

VICTORIA STATION, PIMLICO.

DETAILS OF TRANSVERSE GIRDERS.

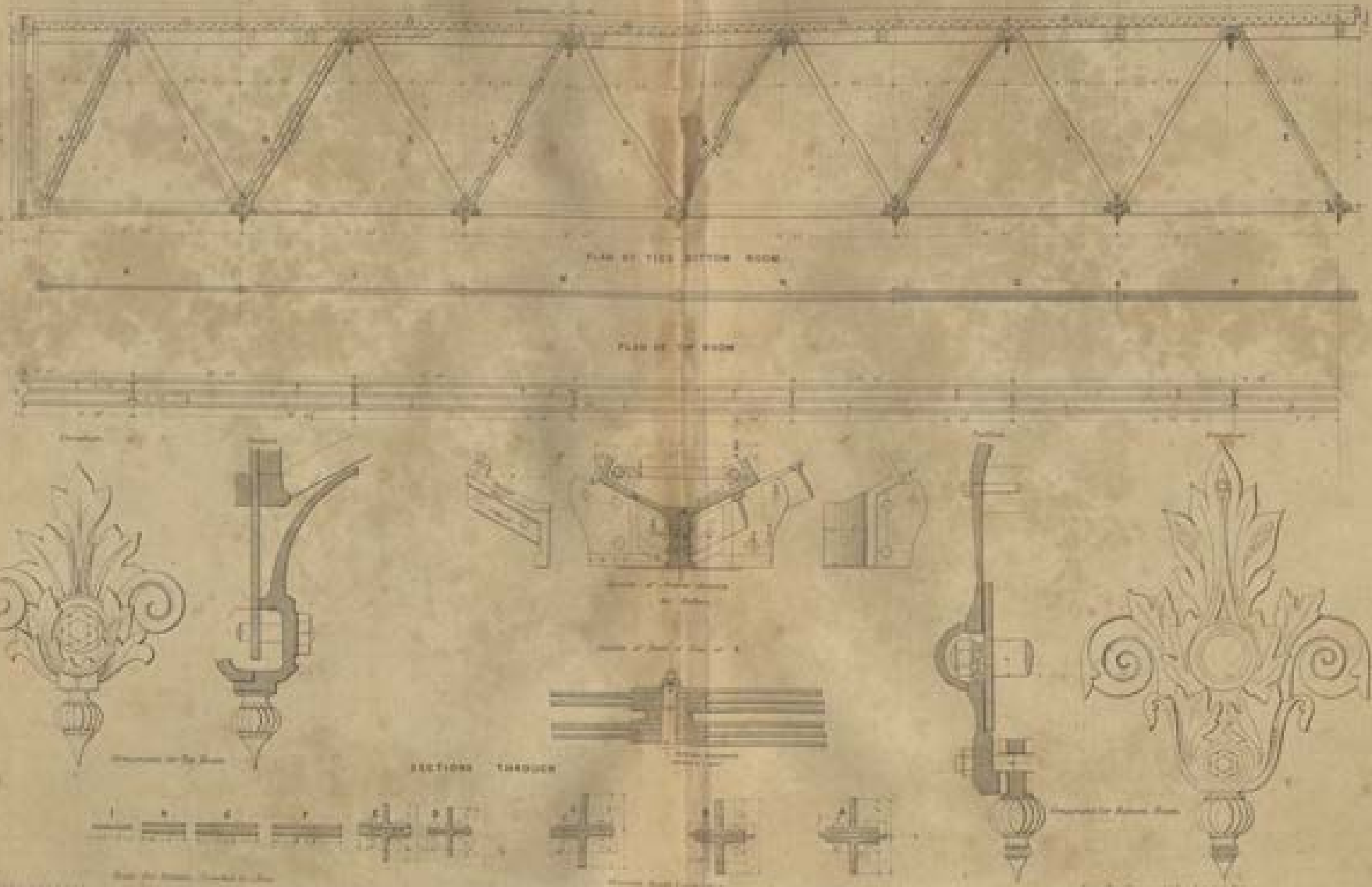


DETAILS OF A AT CAPITAL SIDE



LONDON BRIGHTON AND SOUTH COAST RAILWAY.

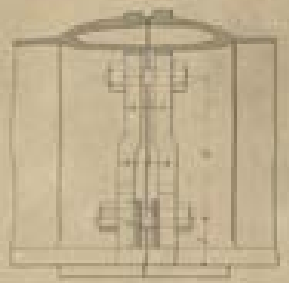
VICTORIA STATION, PIMLICO 1861.

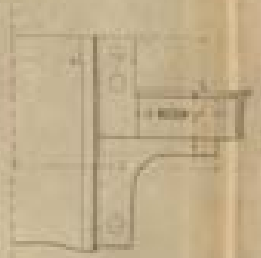


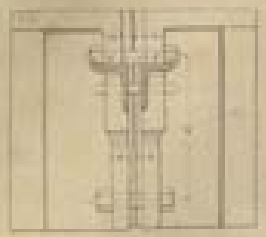
LONDON BRIGHTON AND SOUTH COAST RAILWAY.

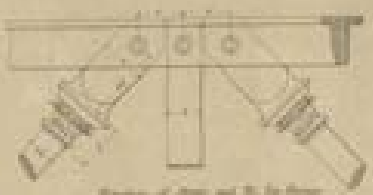
VICTORIA STATION, PIMLICO N°6.

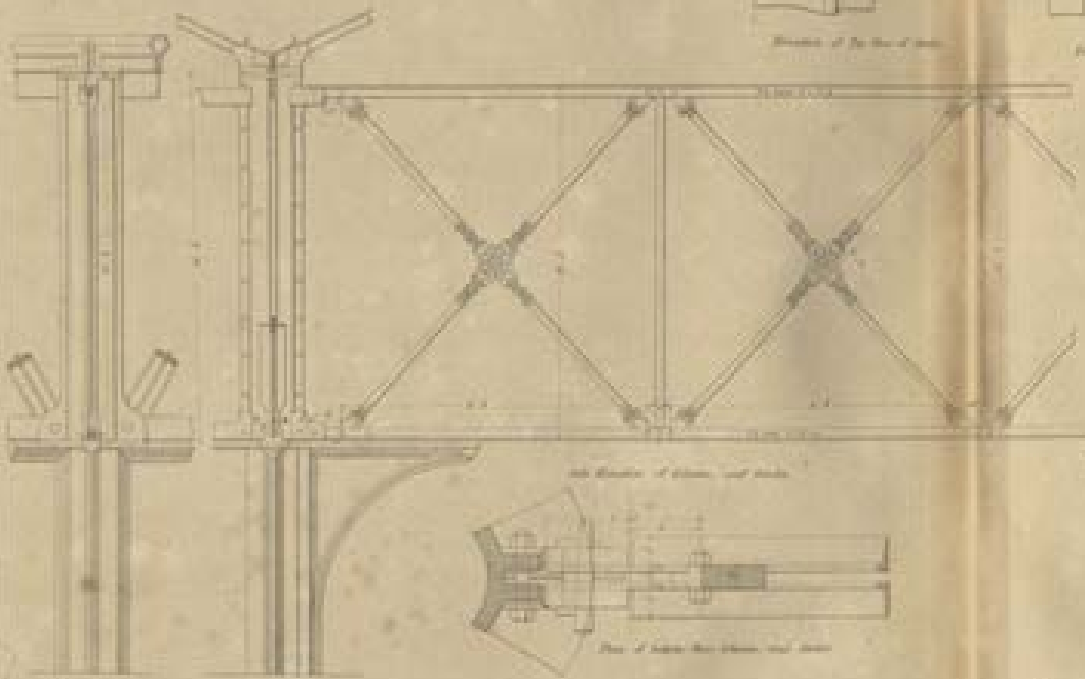
DETAILS OF LONGITUDINAL GIRDERS.









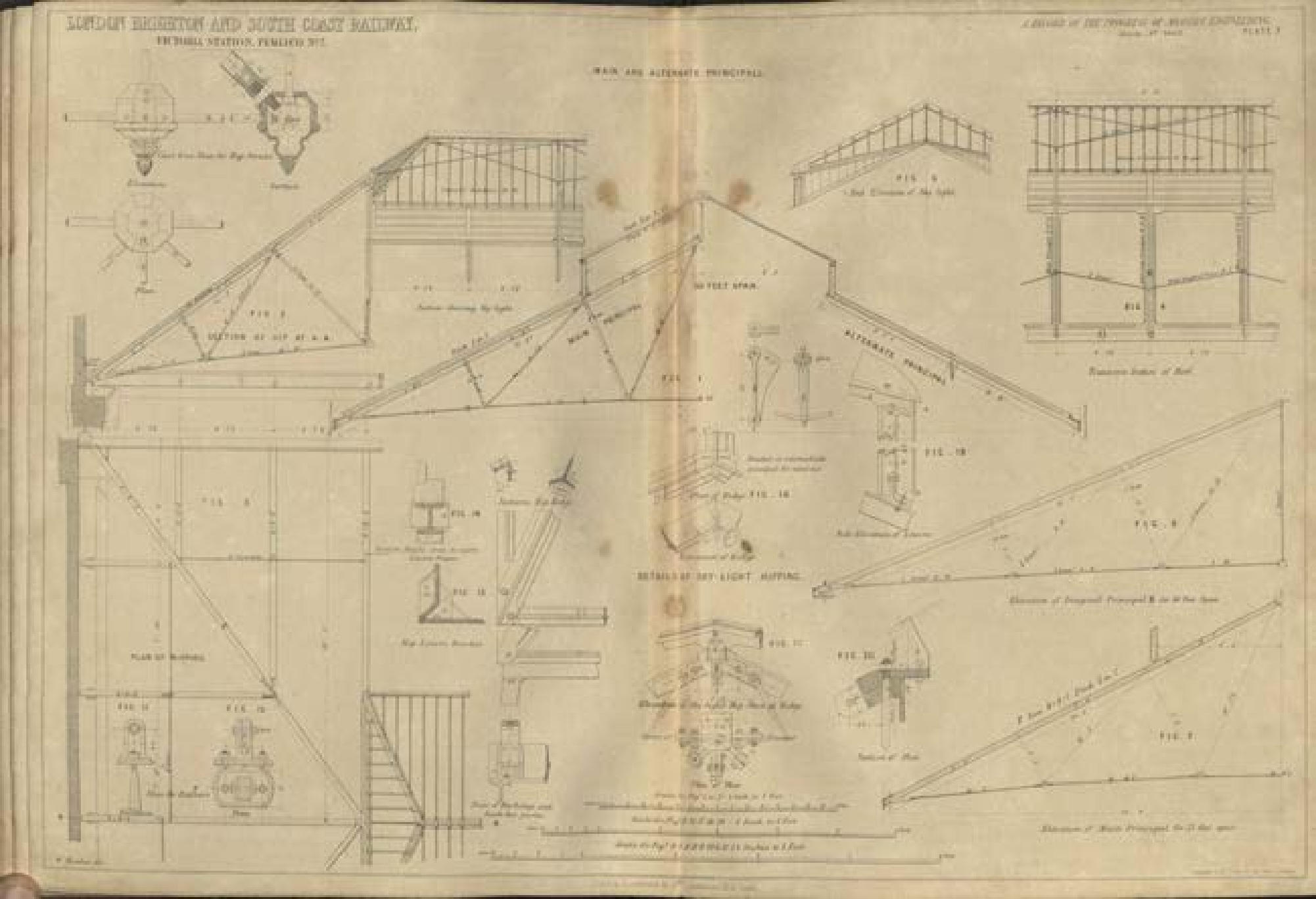


LONDON BRIGHTON AND SOUTH COAST RAILWAY.

VICTORIA STATION, PIMLICO 1862.

MAIN AND ALTERNATE PRINCIPALS

DETAILS OF SKY LIGHT SUPPORT



LONDON BRIGHTON AND SOUTH COAST RAILWAY.

VICTORIA STATION, PIMLICO S.W.

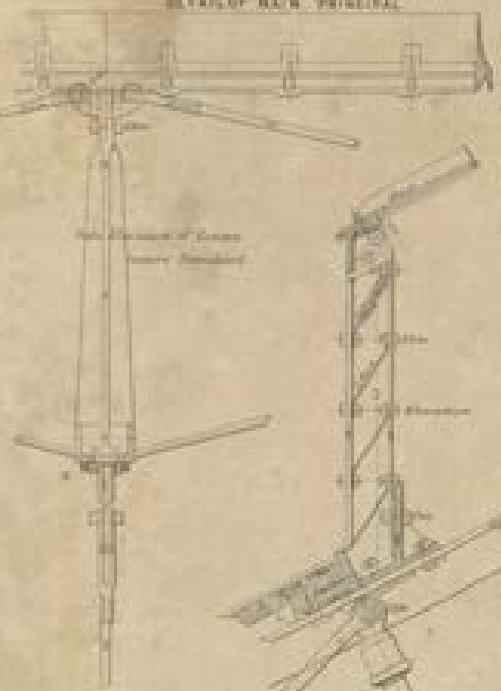
DETAILS OF MAIN PRINCIPAL

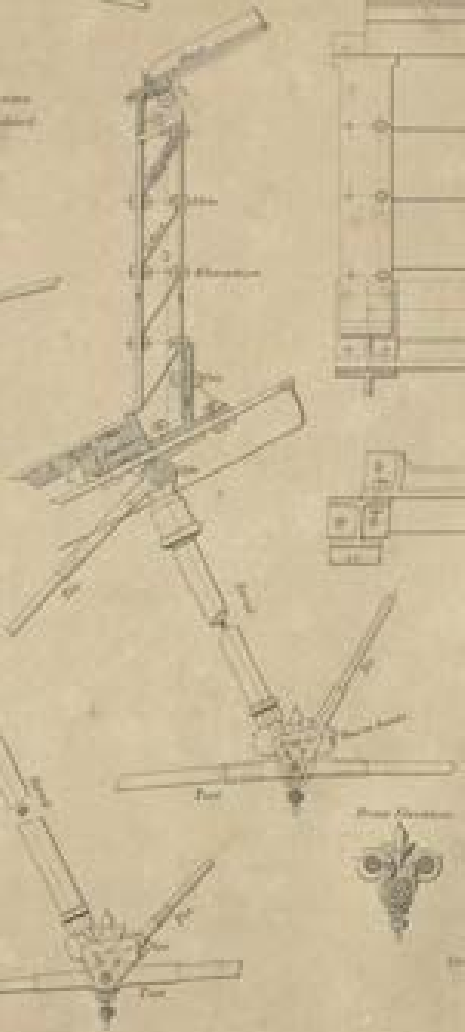
DETAILS OF LOUVRES

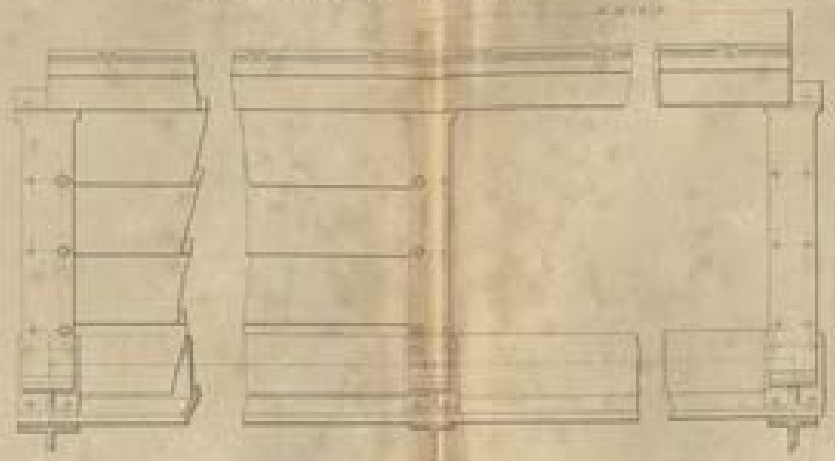
A RECORD OF THE WORKS OF MODERN ENGINEERS

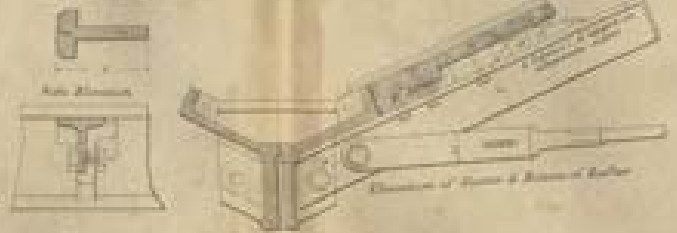
PLATE 8

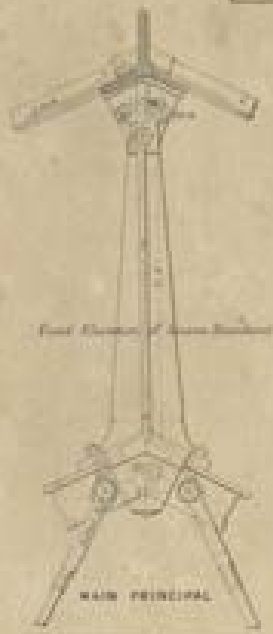
DETAIL OF MAIN PRINCIPAL



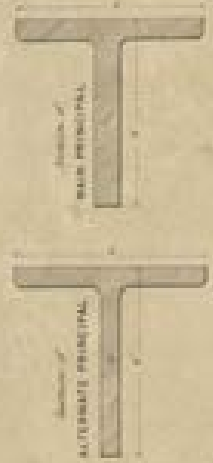


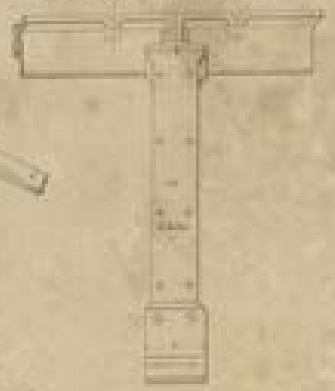




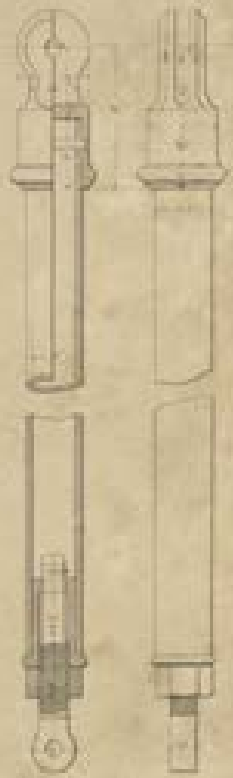


MAIN PRINCIPAL

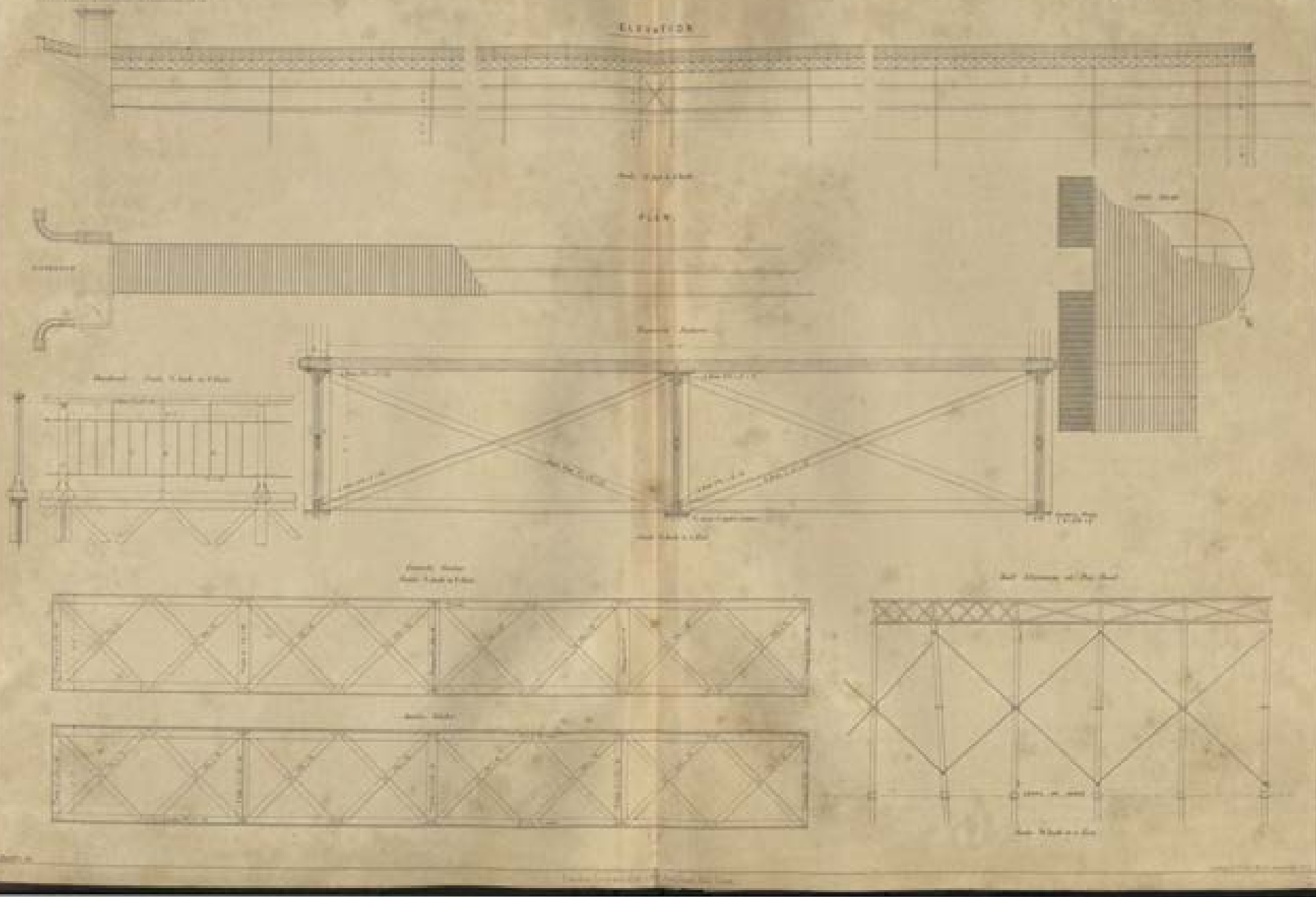




DETAIL OF STRUT A

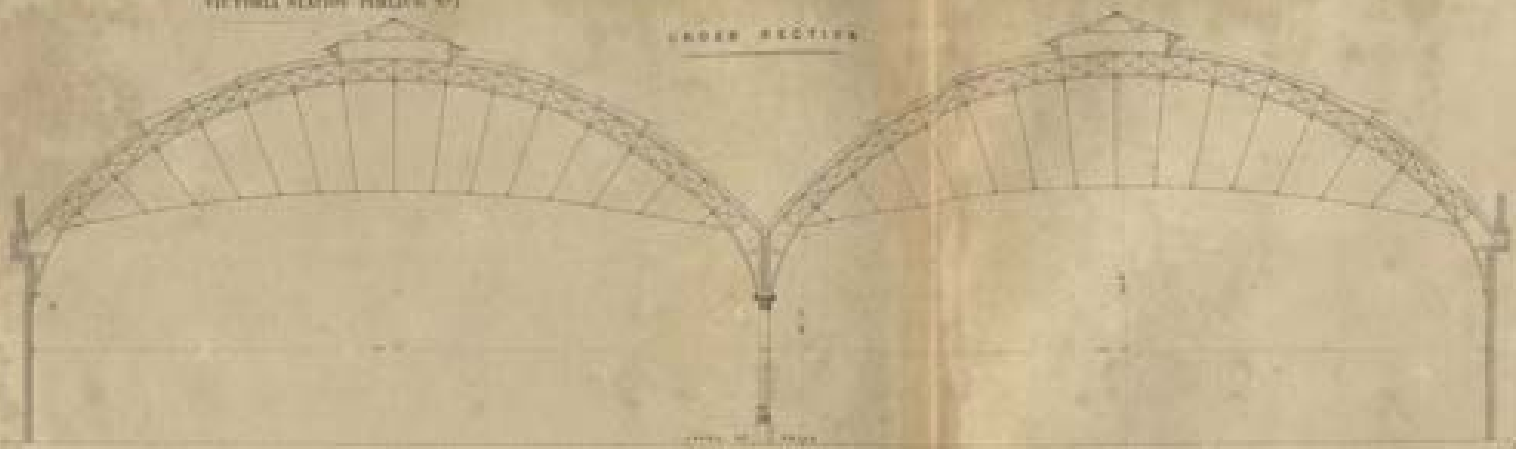


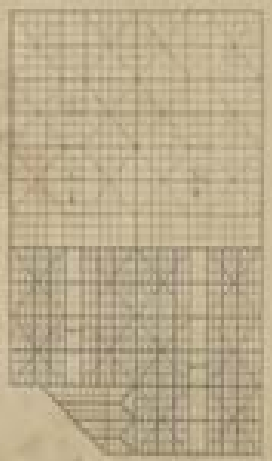
SOUTHPORT PIER No 1.

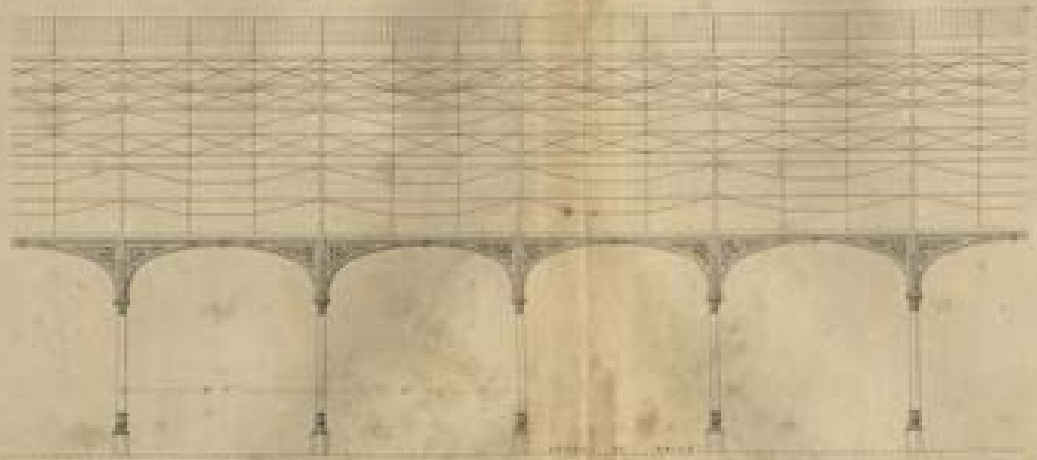


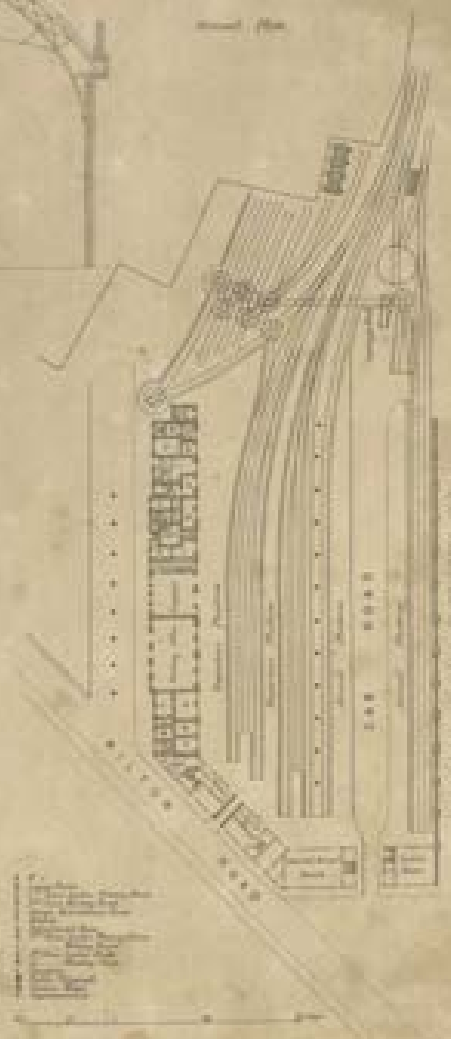
LONDON, CHATHAM, AND DOVER, AND GREAT WESTERN RAILWAY

VICTORIA STATION PIMLICO No 1





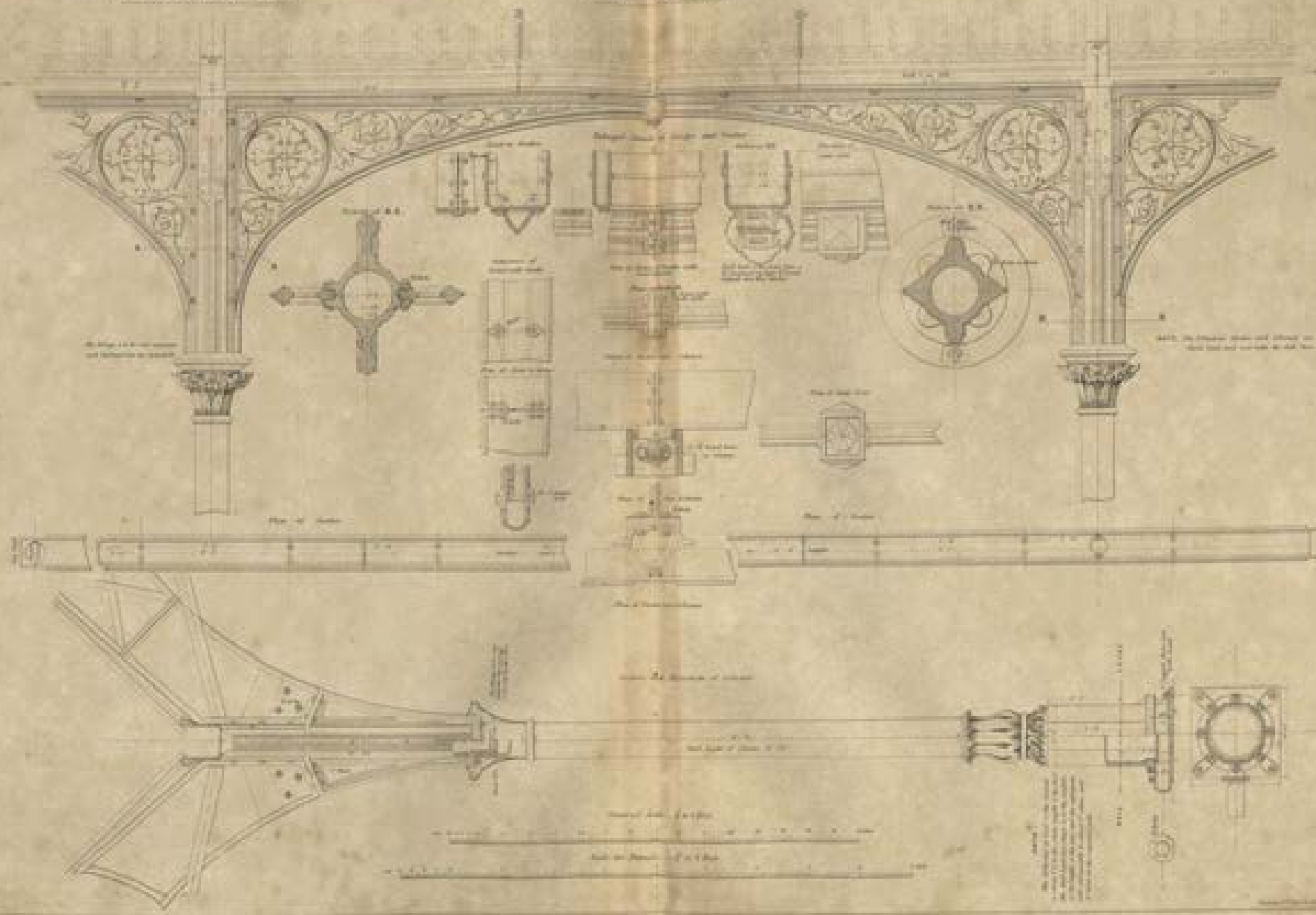




LONDON, CHATHAM AND DOVER, AND GREAT WESTERN RAILWAY.

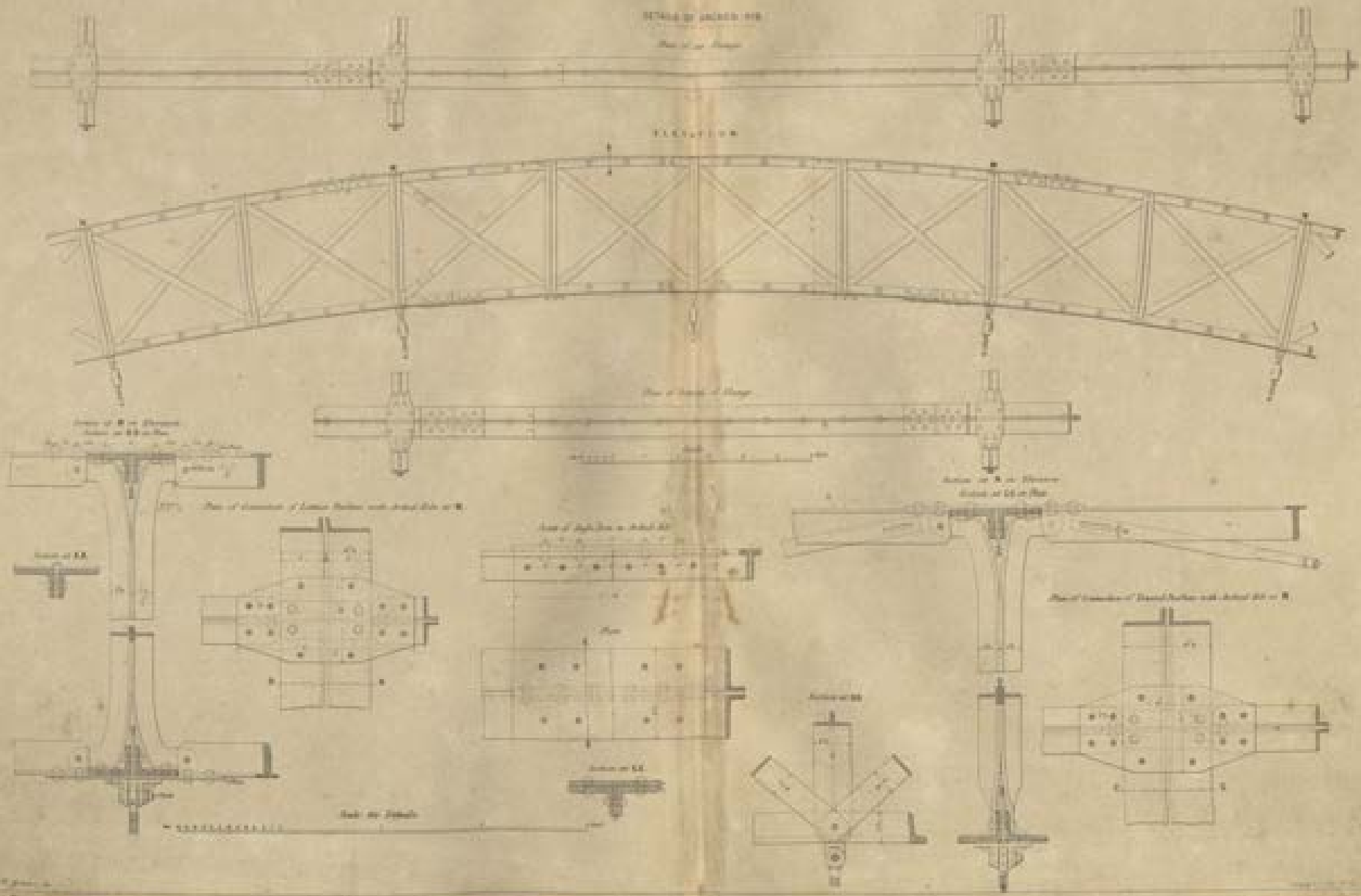
VICTORIA STATION, PIMLICO No 2.

DETAILS OF SPANDRELS.



LONDON, CHATHAM AND DOVER, AND GREAT WESTERN RAILWAY.

VICTORIA STATION, PIMLICO SPUR.

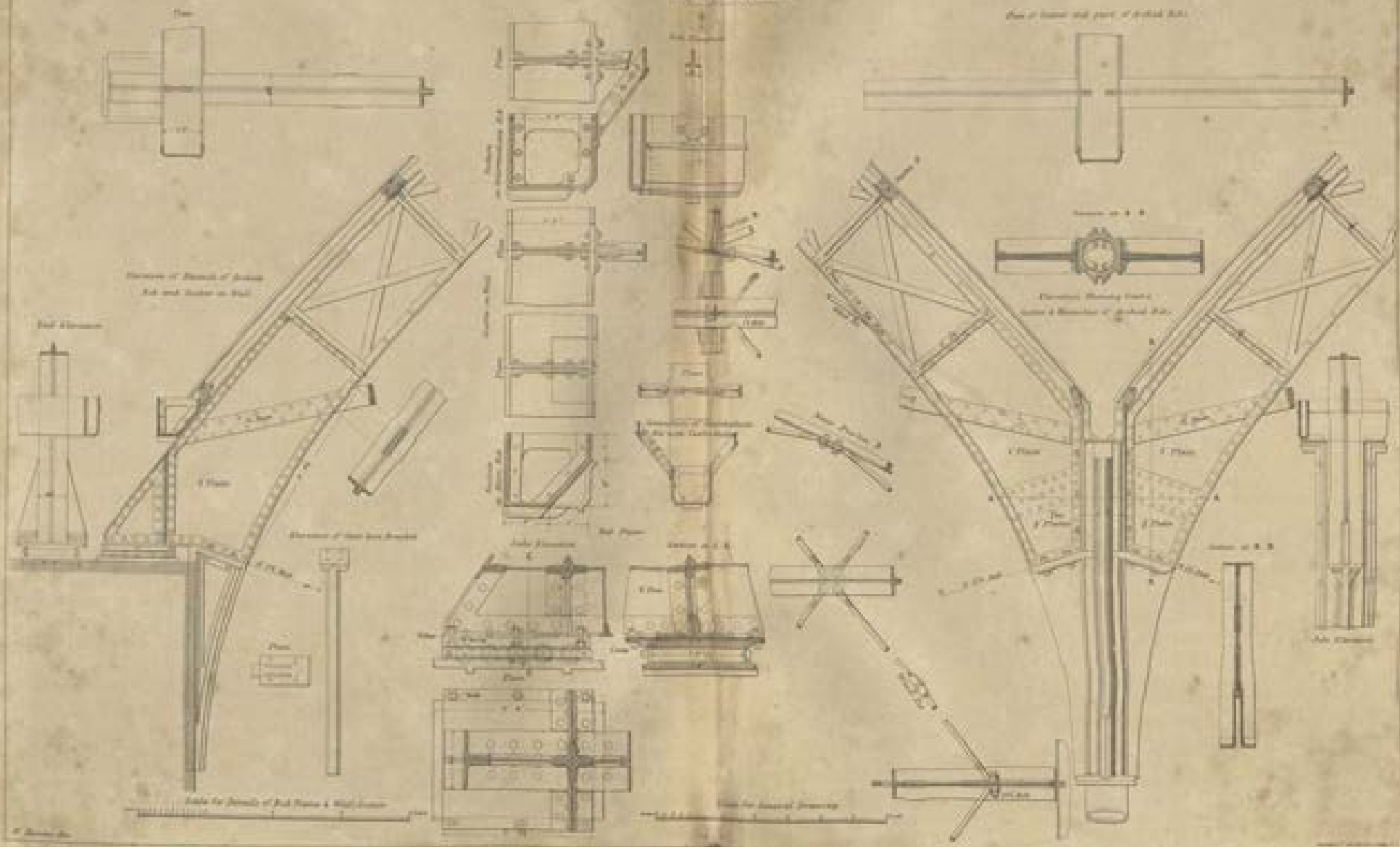


LONDON, CHATHAM AND DOVER, AND GREAT WESTERN RAILWAY.

VICTORIA STATION PIMLICO S.W.

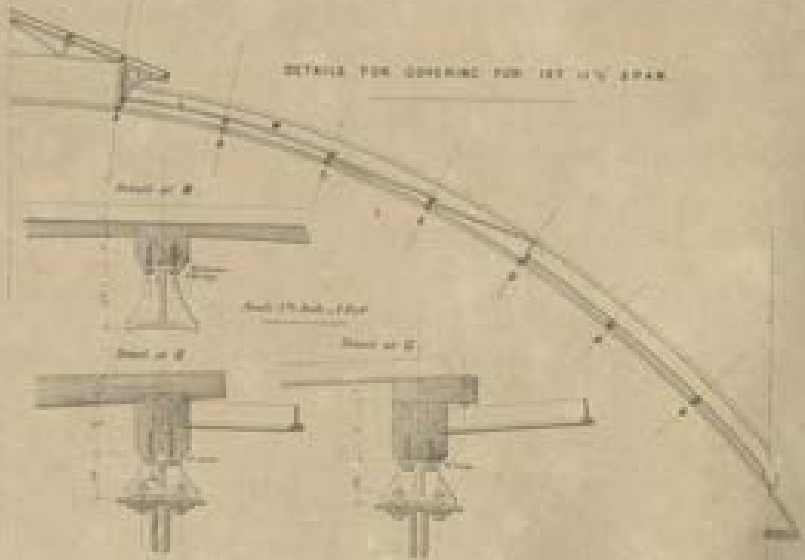
ABRIDGED FROM THE MINUTES OF MINUTES OF ENGINEERING.
Mar 2nd 1861. PLATE 18

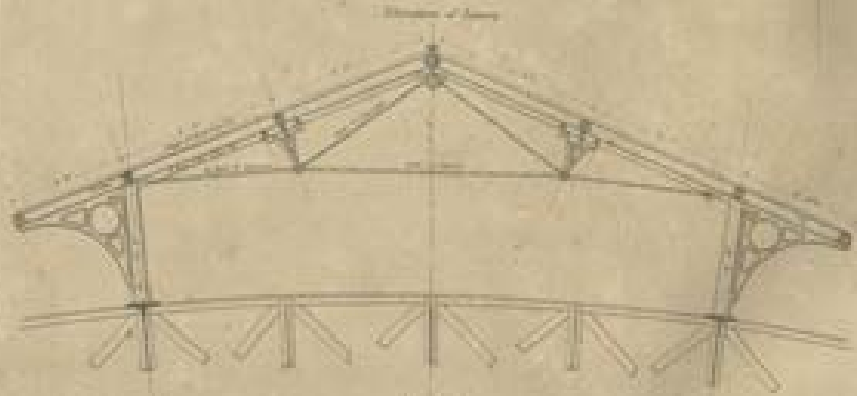
DETAILS OF R.B.



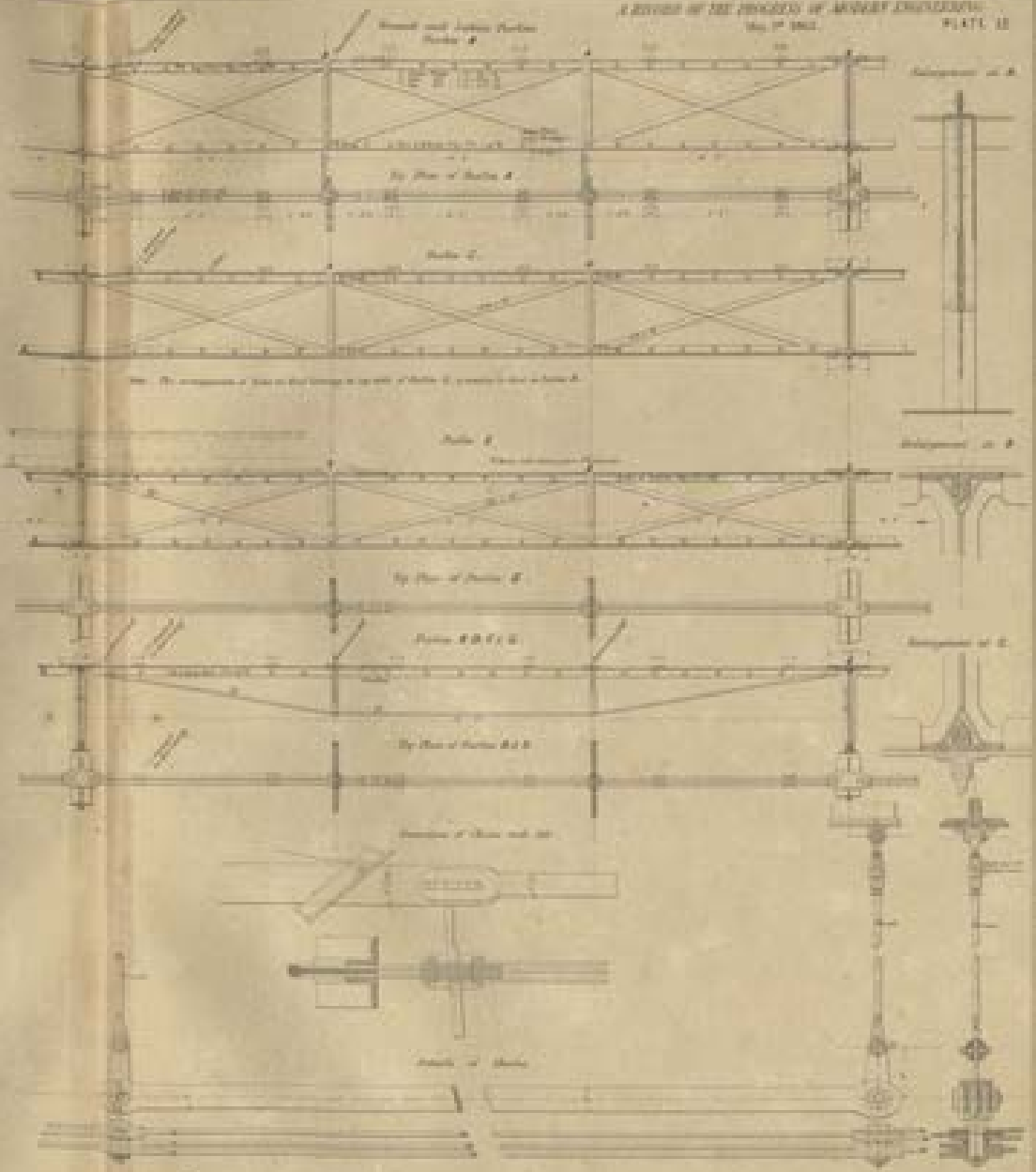
LONDON, CHATHAM AND DOVER AND GREAT WESTERN RAILWAYS.

VICTORIA STATION PIMLICO N°2





SCALES.



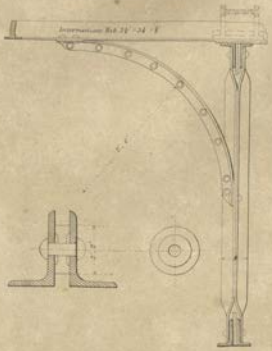
LONDON, CHATHAM AND DOVER, AND GREAT WESTERN RAILWAY.

VICTORIA STATION, PIMLICO Sr. 6

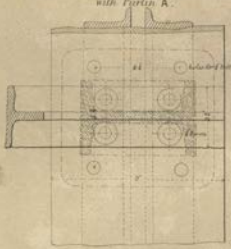
A RECORD OF THE PROGRESS OF MODERN ENGINEERING. 1863.
June 1st 1865. PLATE 15A

DETAILS OF TRUSSED & LATTICE PURLINS.

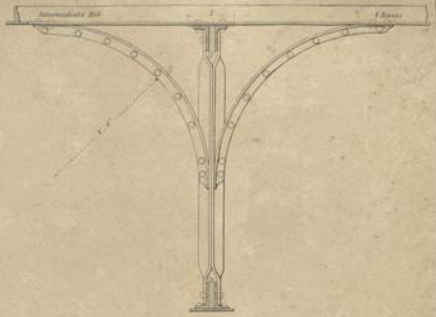
Transverse Section of Purlin A.



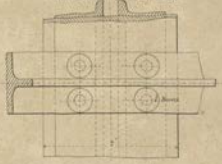
Detail of Connections of Intermediate Rib with Purlin A.



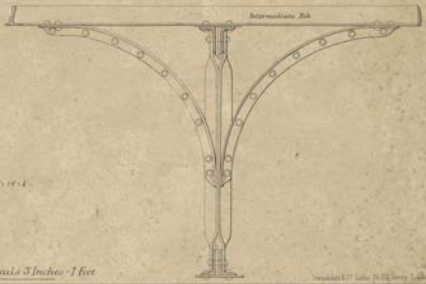
Transverse Section of Purlin C.



Detail of Connections of Intermediate Rib with Purlins B.D.F.&C.

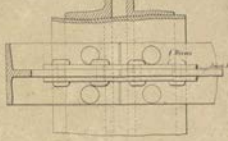


Transverse Section of Purlin E.



Transverse Section of Purlins B.D.F.&C.

Joint in Intermediate Rib over Purlins C.&E.



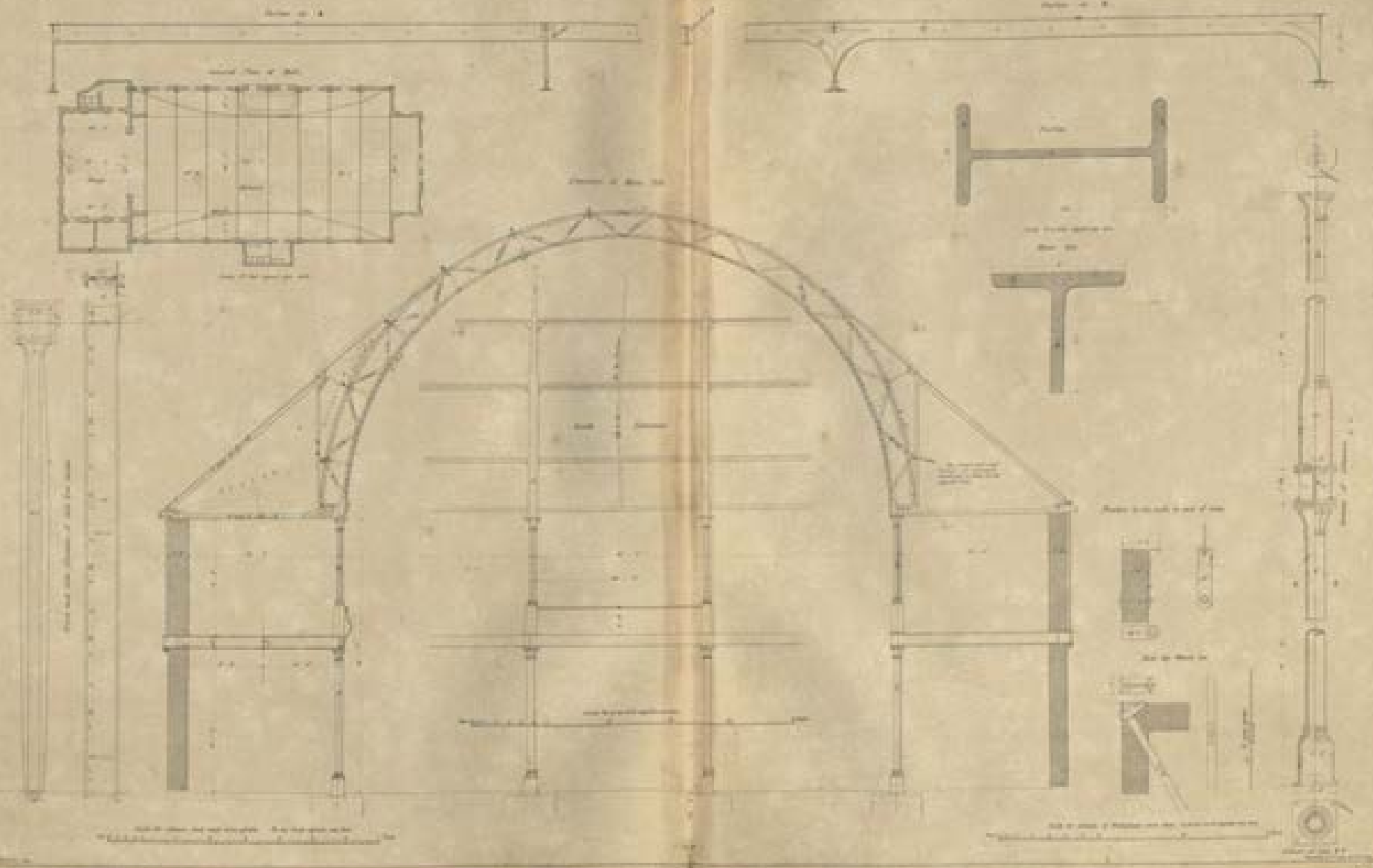
W. Bromley Dr.

Scale for Cross Sections 1 Inch = 1 Foot

Scale for Details 3 Inches = 1 Foot

London: Longmans & Co. 39 Paternoster Row. Edinburgh: A. & C. Black. Dublin: Hodges & Smith. Glasgow: R. Griffin & Co.

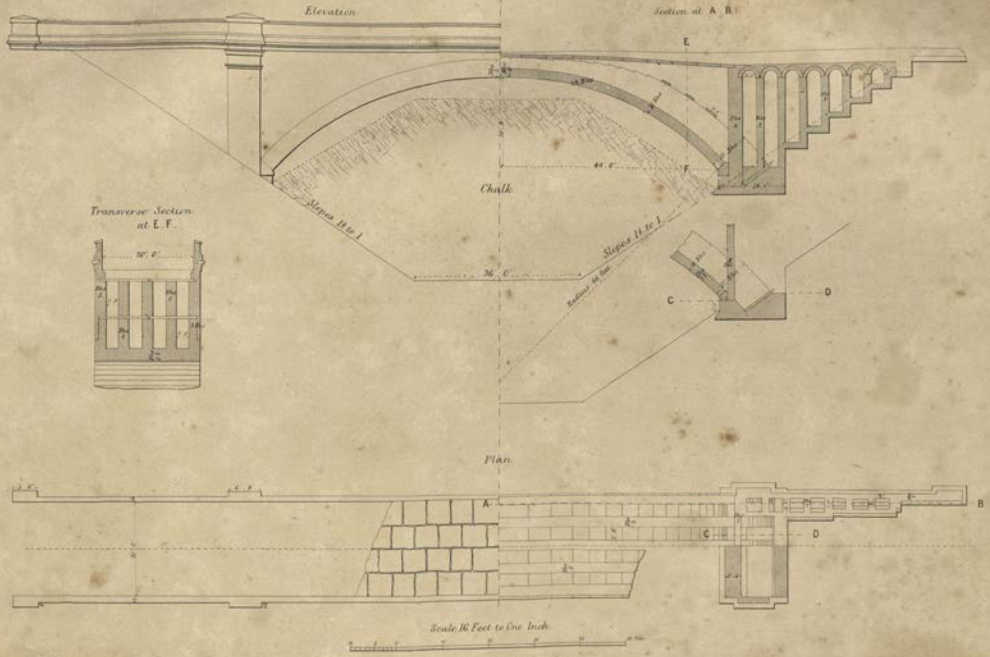
CREMORNE MUSIC HALL ROOF.



GREAT NORTHERN RAILWAY.

PARISH ROAD BRIDGE, KNEBWORTH.

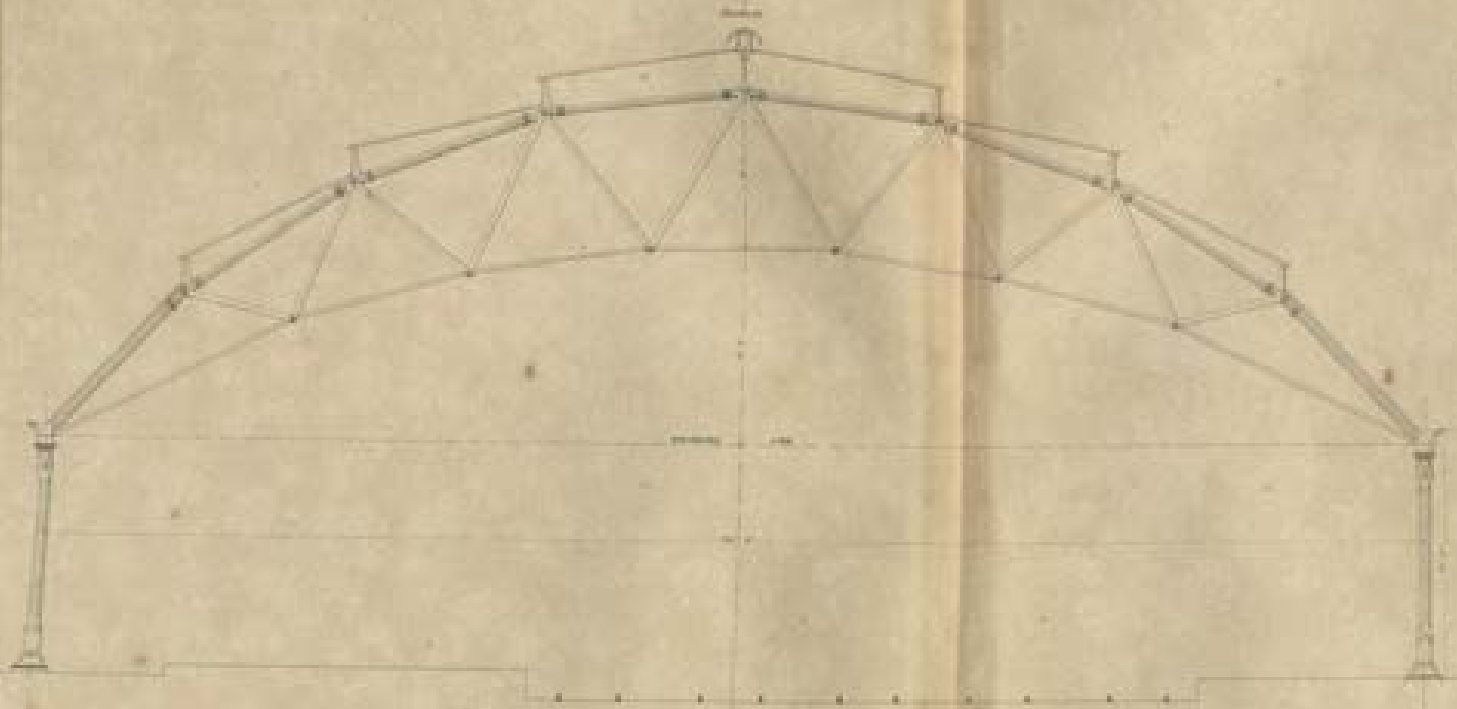
A RECORD OF THE PROGRESS OF MODERN ENGINEERING. 1863.
June 1st 1863.
PLATE 17.

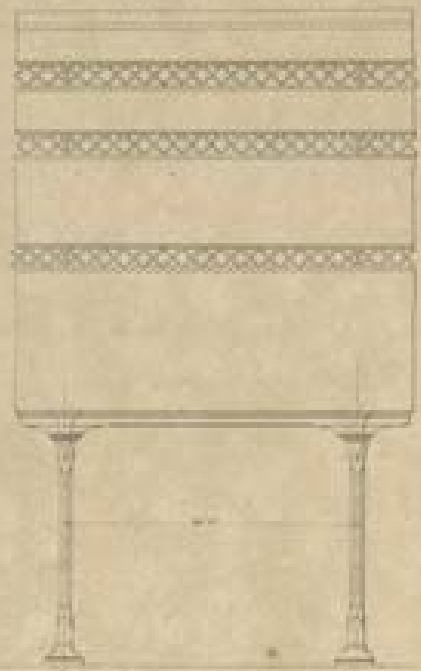


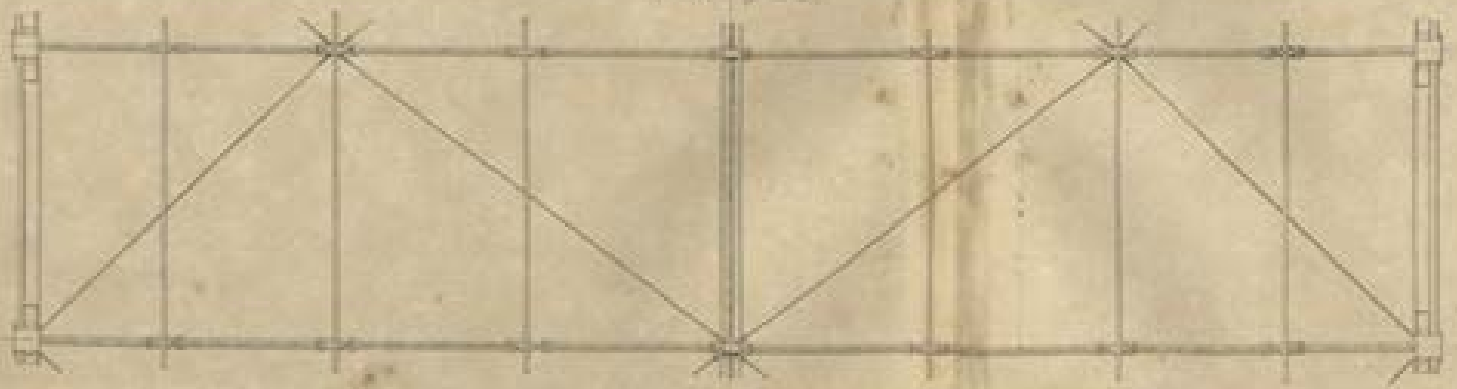
DUTCH RHENISH RAILWAY.

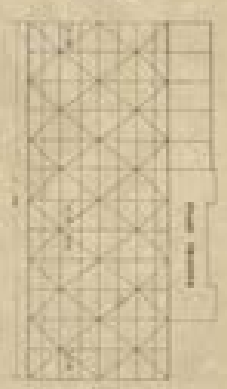
AMSTERDAM STATION. N°1.

ELEVATION SECTION AND PLAN OF ONE BAY OF ROOF







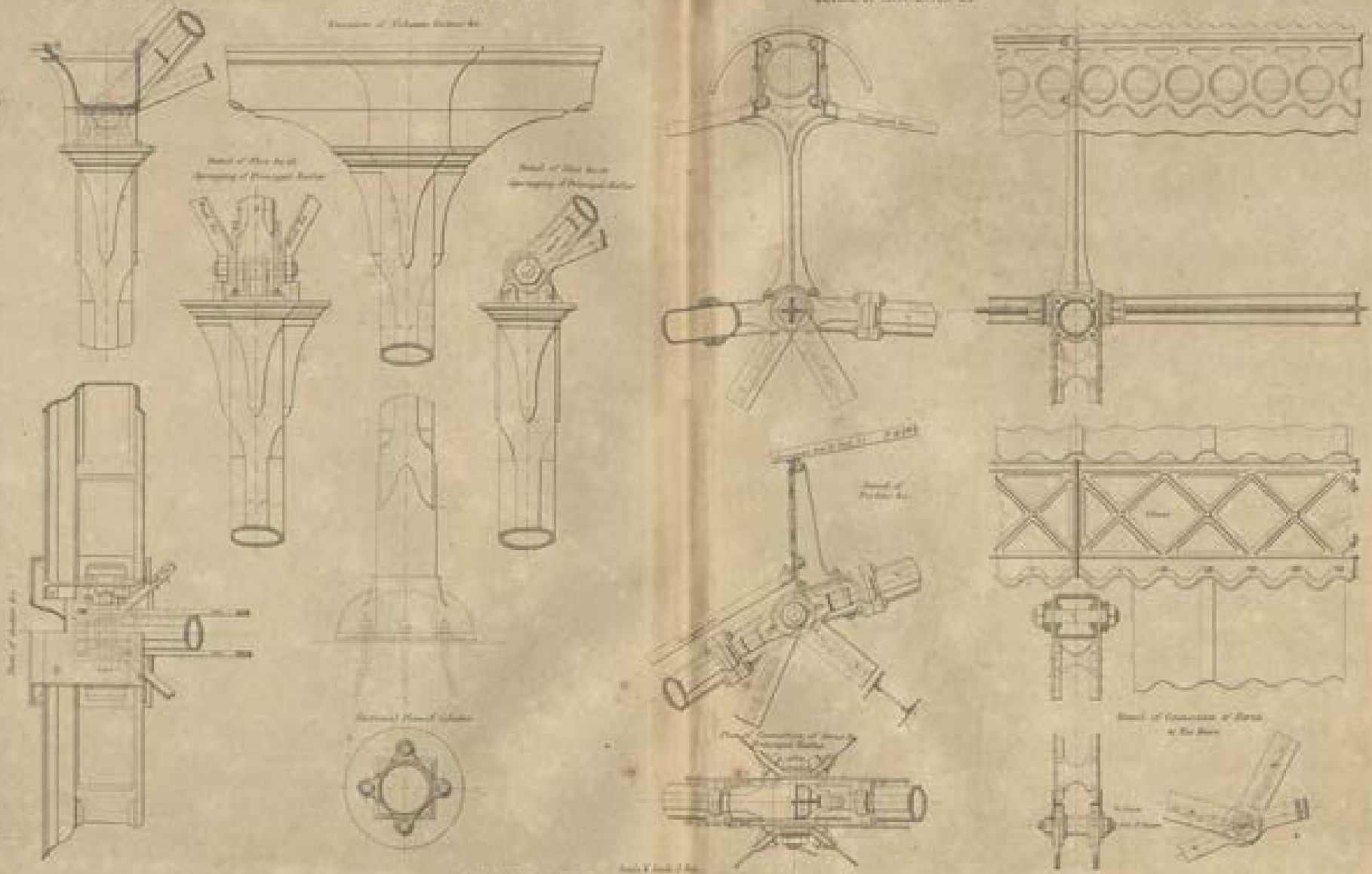


DUTCH RHENISH RAILWAY.

AMSTERDAM STATION N° 2.

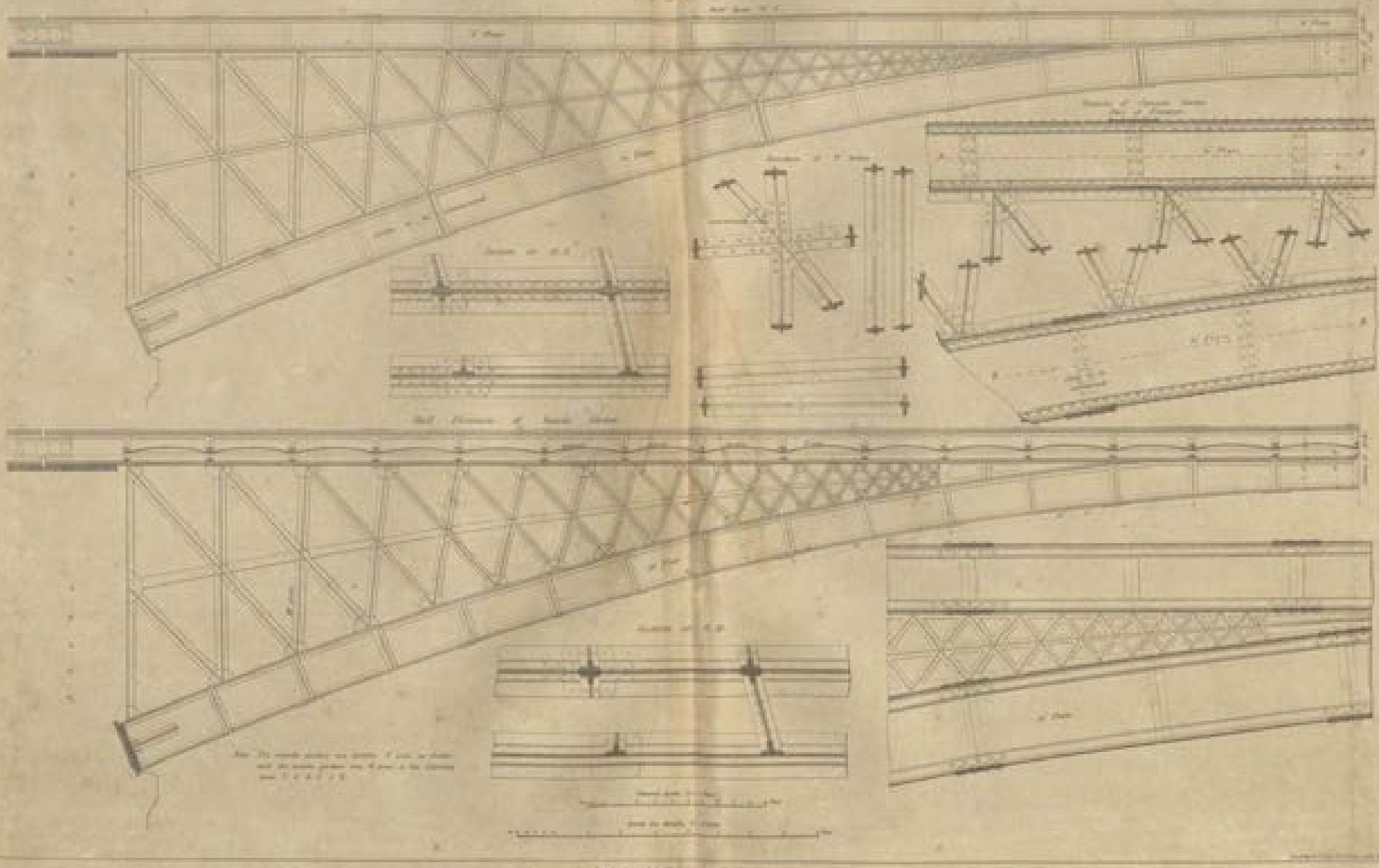
DETAILS OF COLUMNS & ROOF

DETAIL OF VENTILATOR &c.



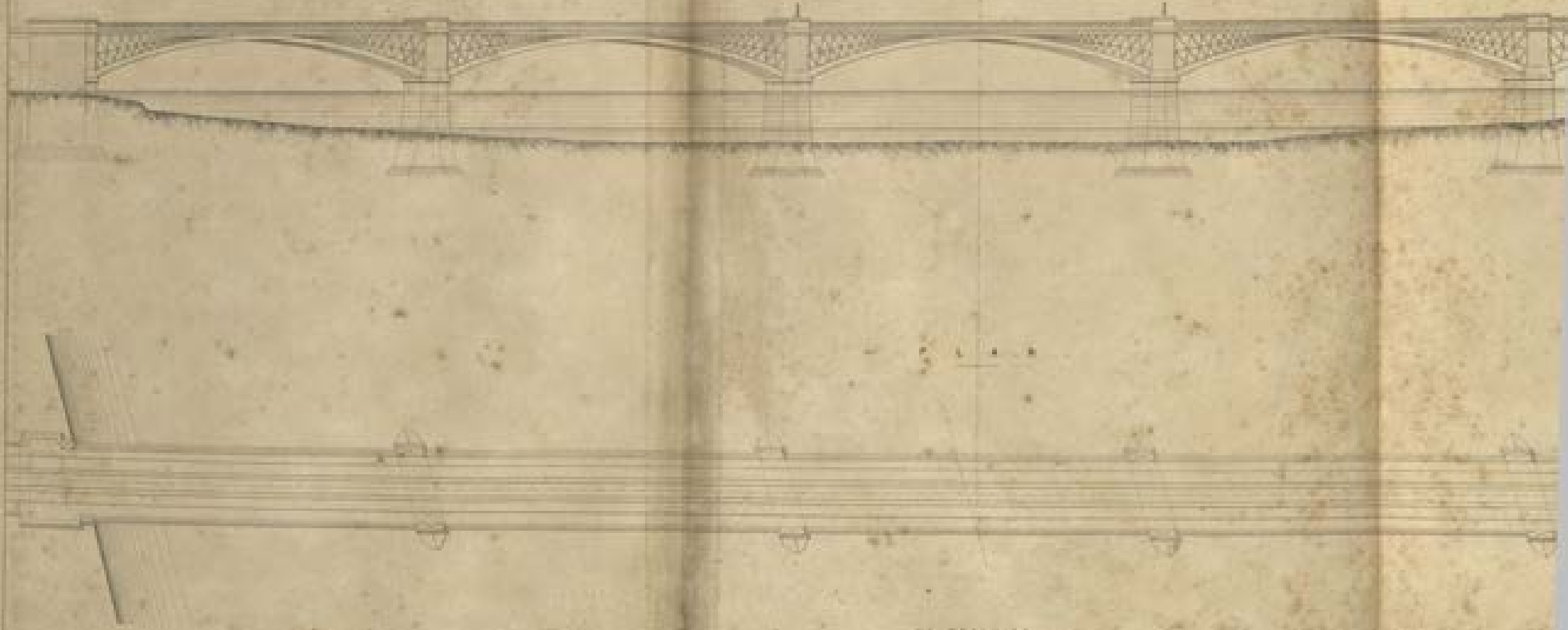
WEST LONDON EXTENSION RAILWAY.

BRIDGE OVER THE THAMES. N°2.



WEST LONDON EXTENSION RAILWAY

GENERAL ELEVATION



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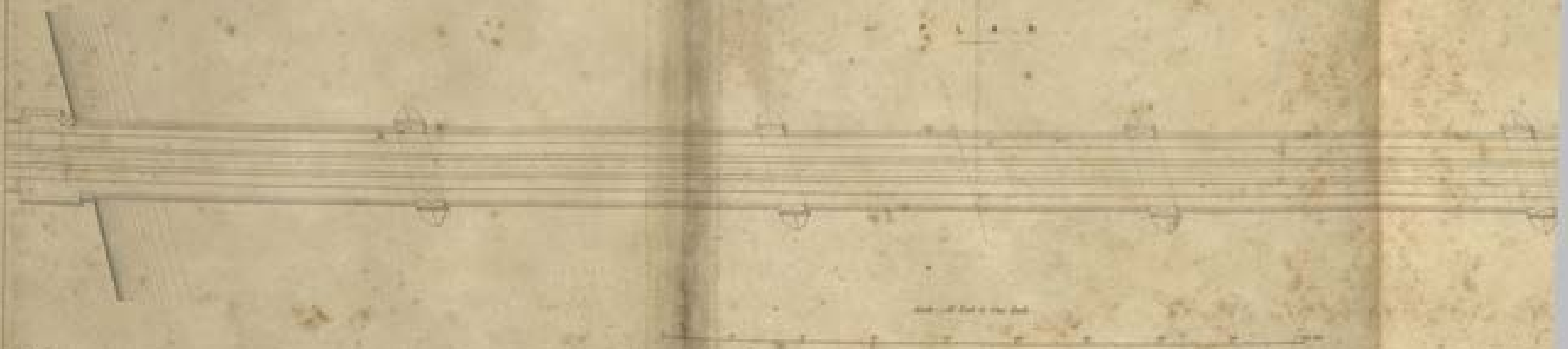
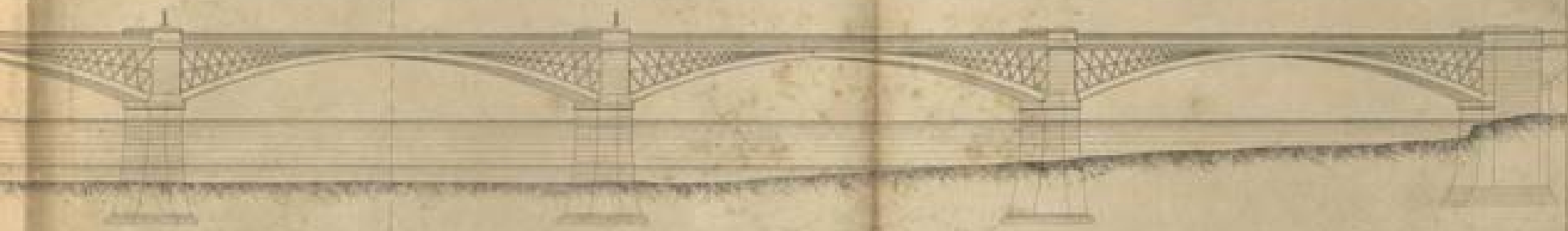
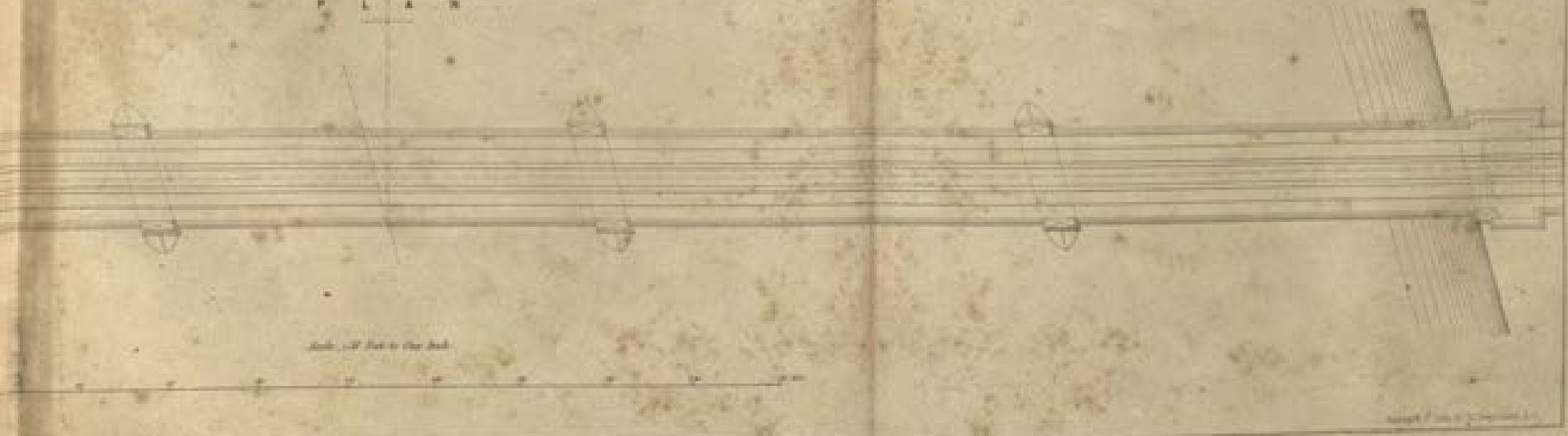

GENERAL ELEVATION

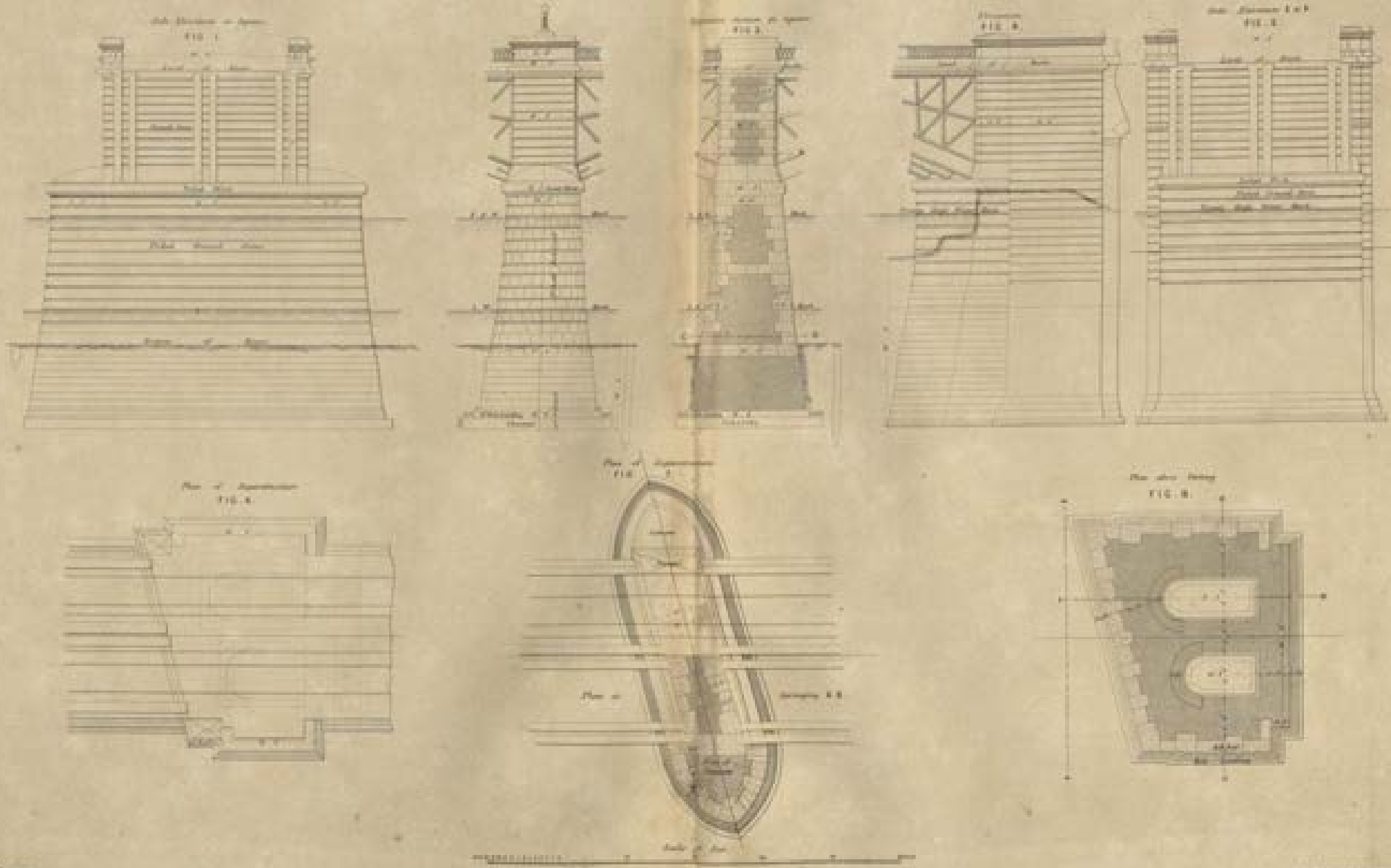


PLAN

WEST LONDON EXTENSION RAILWAY.

BRIDGE OVER THE THAMES. N° 6.

PLATE XX.

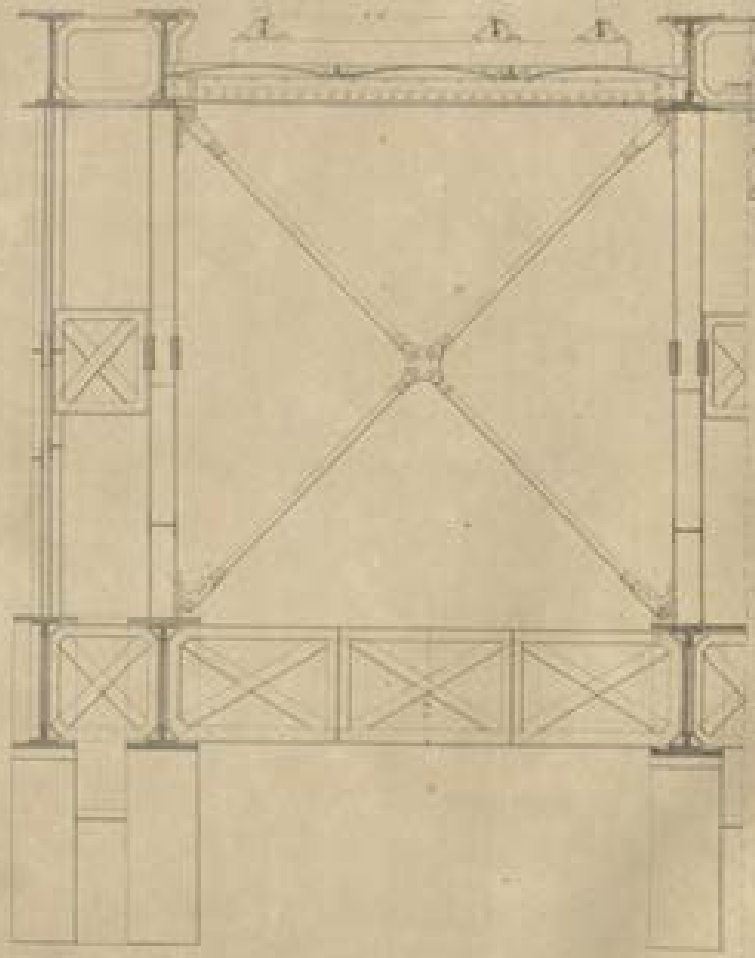
DETAILS OF MASONRY — PIERS.

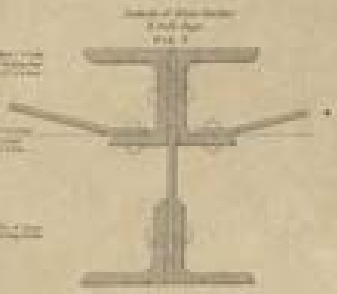


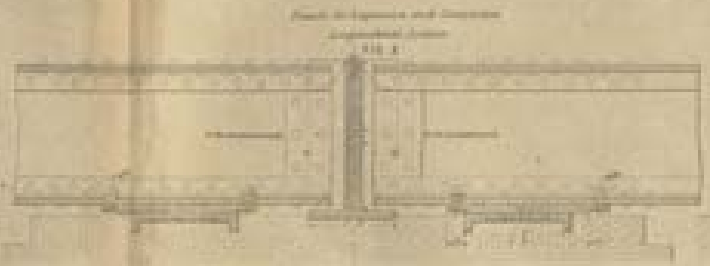
WEST LONDON EXTENSION RAILWAY.

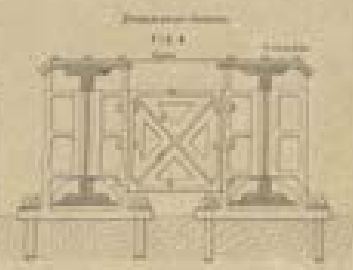
BRIDGE OVER THE THAMES. No 3.

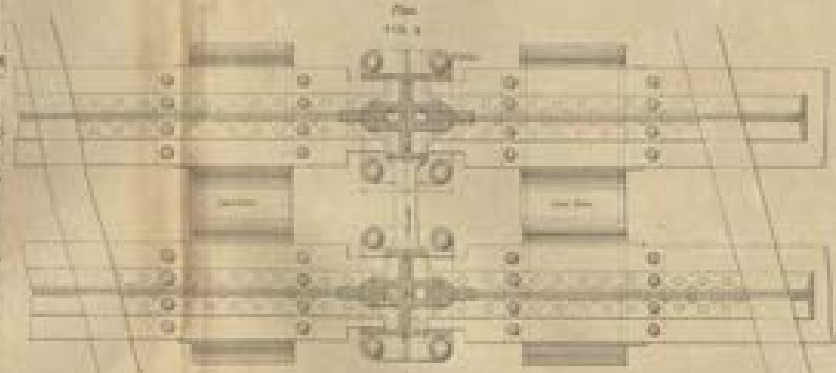
CROSS SECTION







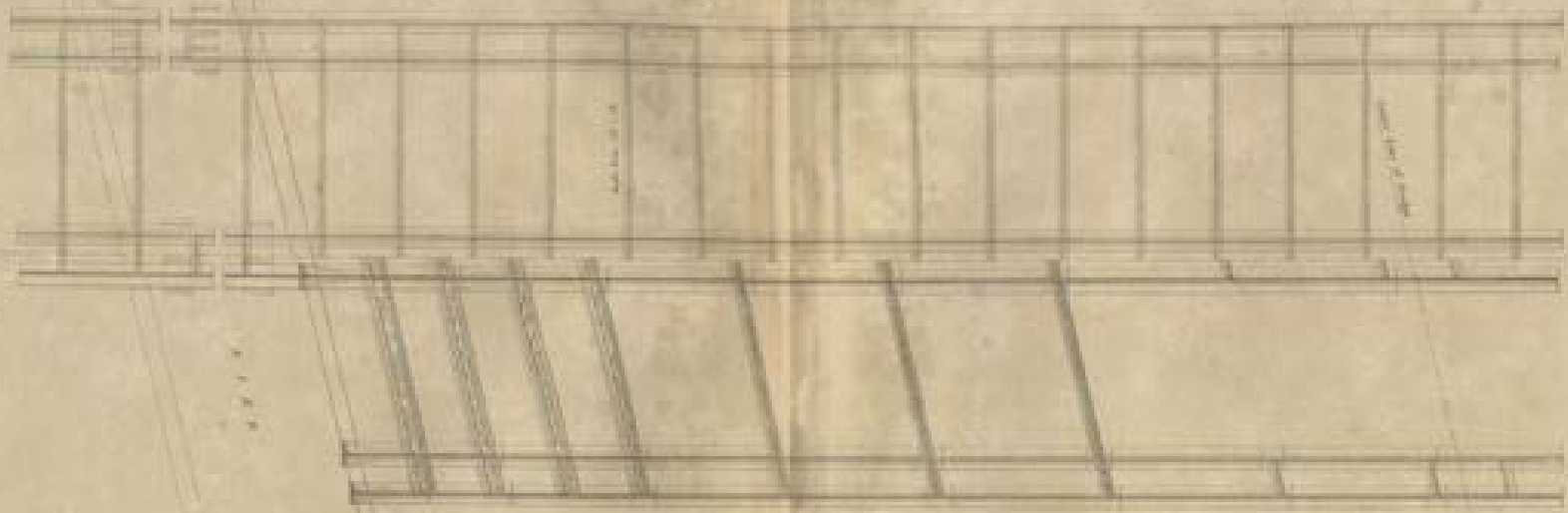


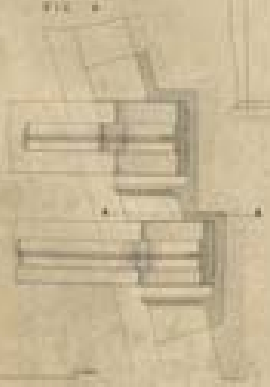


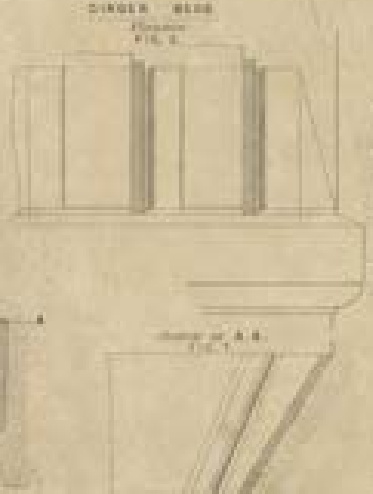
WEST LONDON EXTENSION RAILWAY.

BRIDGE OVER THE THAMES. N° 1.

DETAILS







ARMOUR PLATES.

SECTIONS.

September 1st 1863.

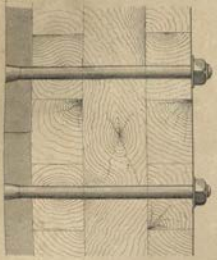


FIG. 1. TRUSTY

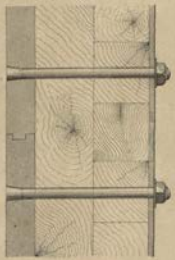


FIG. 2. WARRIOR

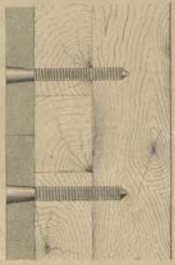


FIG. 3. LA GLOIRE.

FIG. 4. HAWKSHAW

FIG. 5. THE COMMITTEE

FIG. 6. SARUDA.

FIG. 7. SCOTT RUSSELL

FIG. 8. CHALMERS.

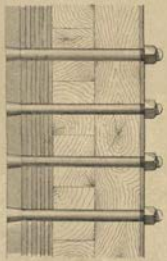
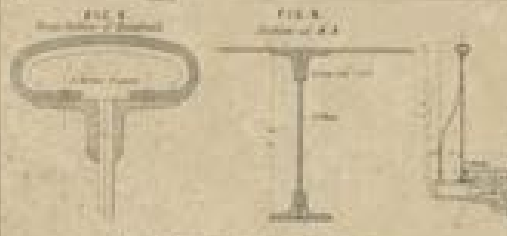


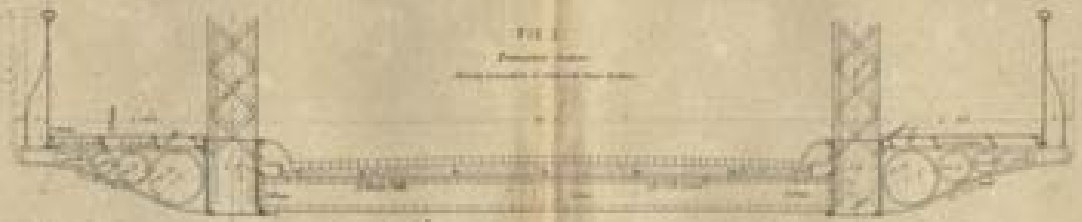
FIG. 9. STEVENS BATTERY

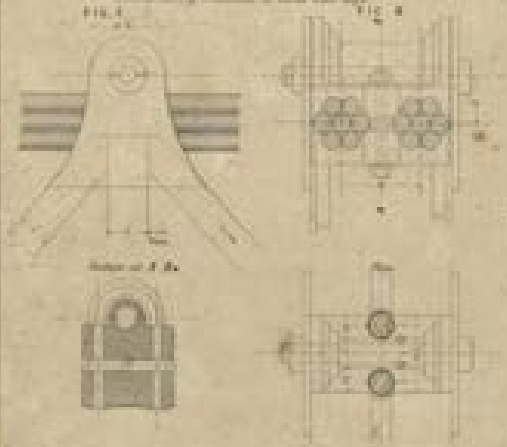
FIG. 10. MERRIMAC.

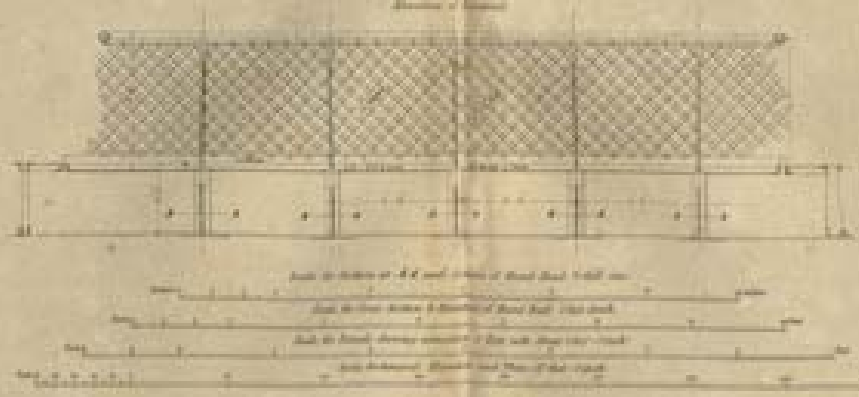
London: Lockwood & Co. 7 Stationers Hall Court.

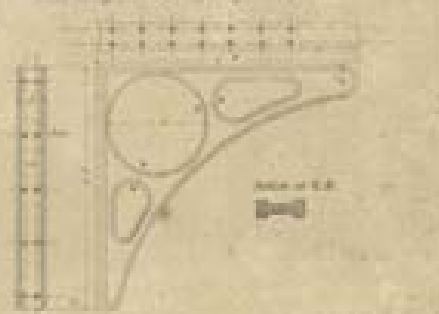
LAMBETH SUSPENSION BRIDGE.





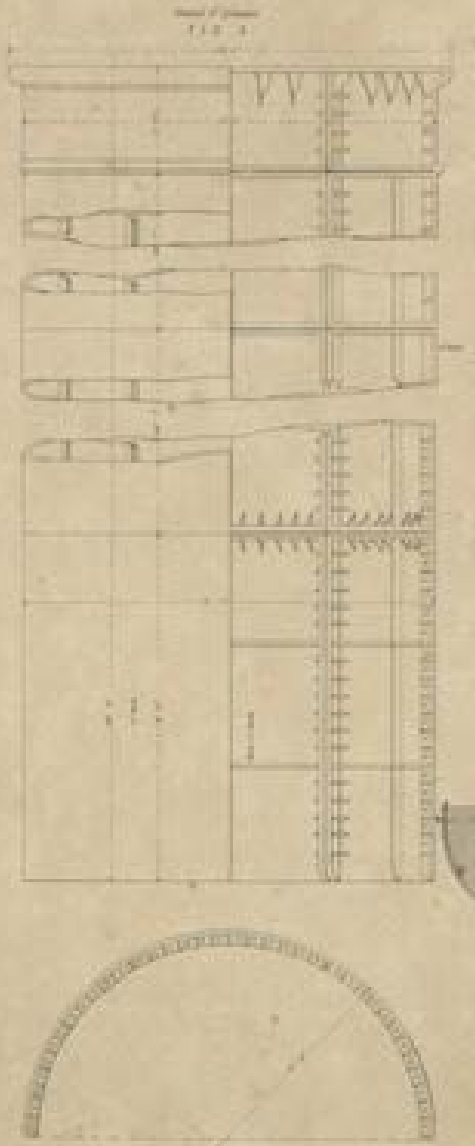


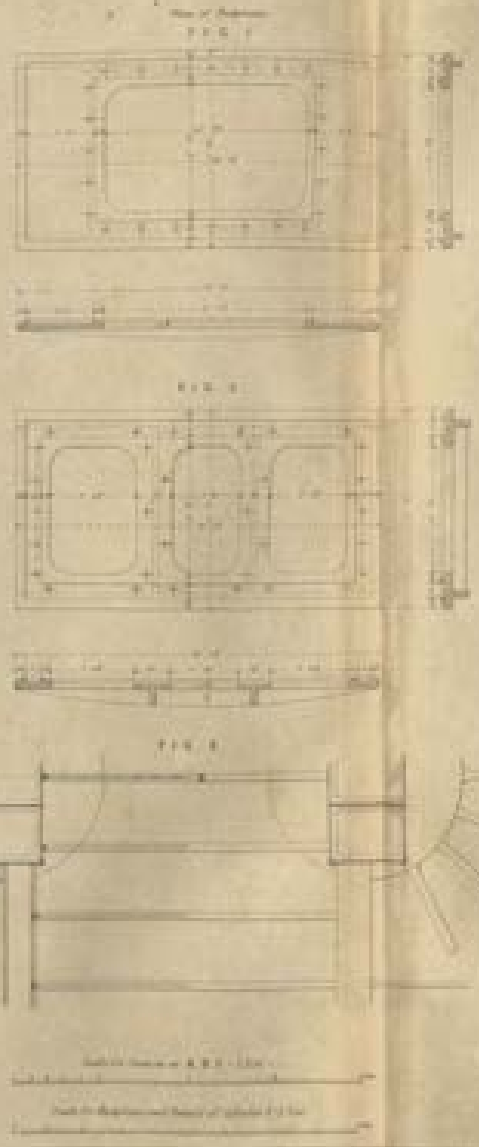


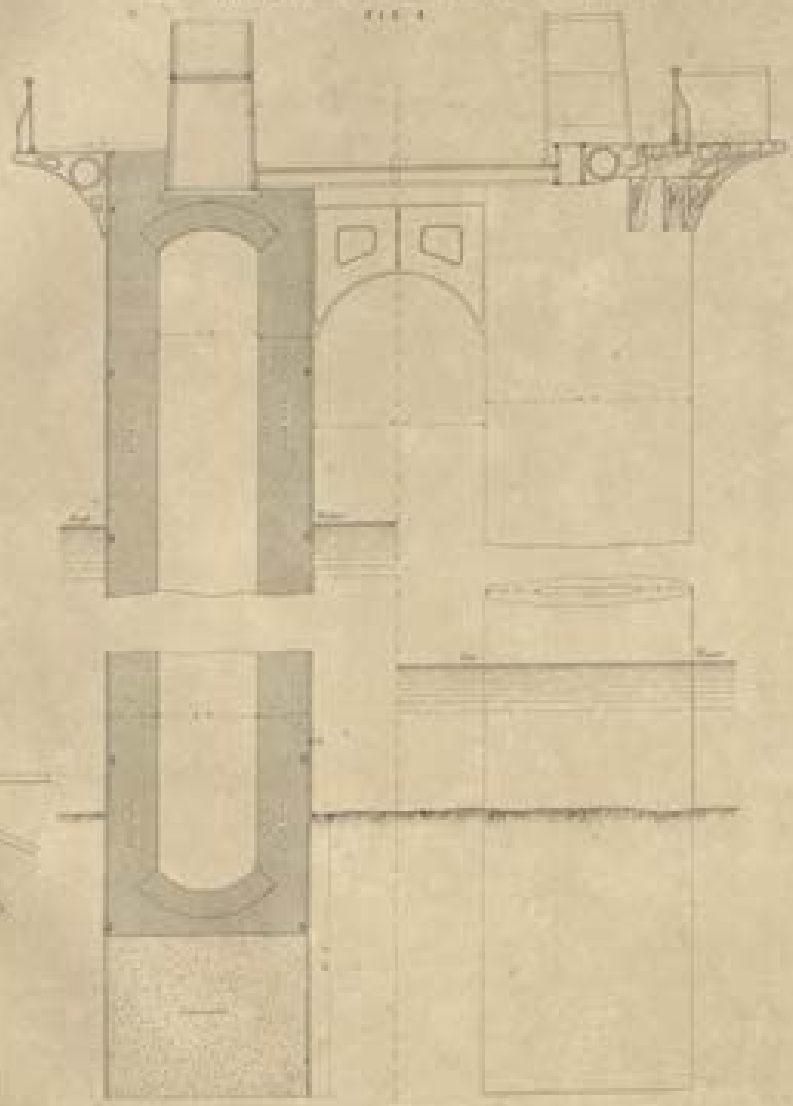


LAMBETH SUSPENSION BRIDGE.

DETAILS OF CYLINDERS & ANCHORAGE.

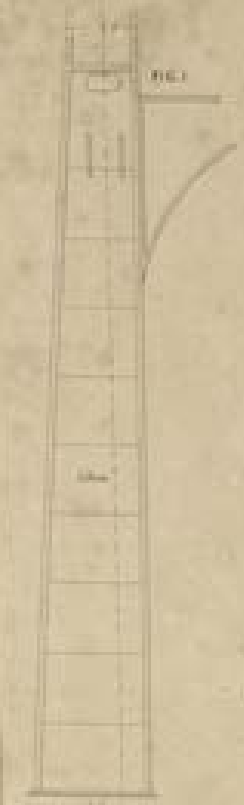


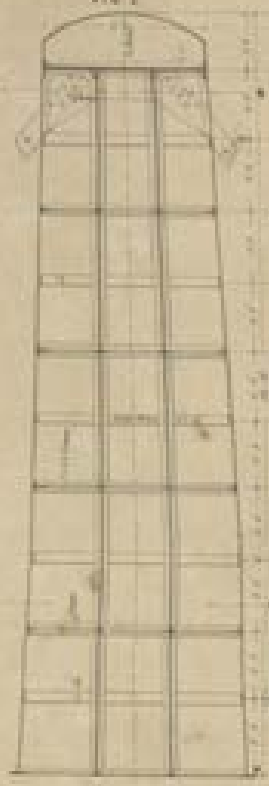


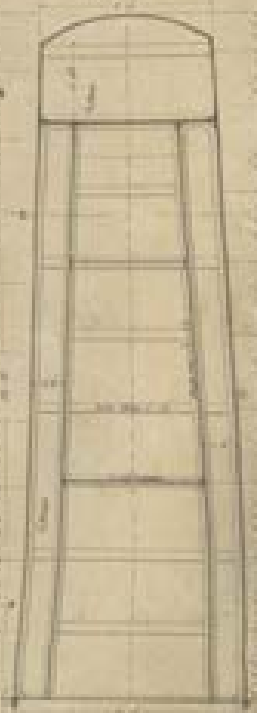


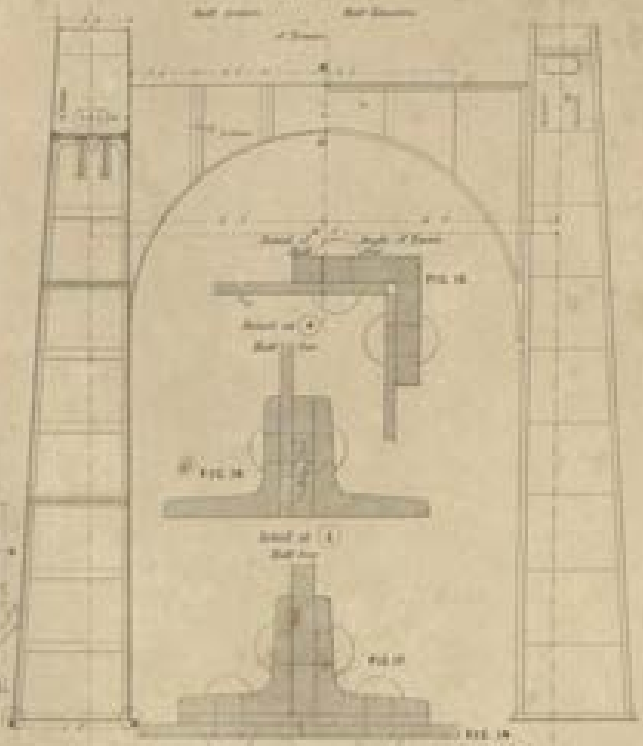
LAUREL SUSPENSION BRIDGE.

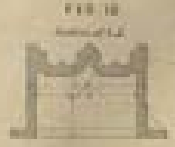
DETAILS OF TOWER AND CABLES.

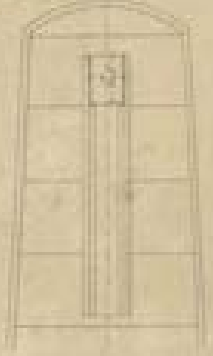








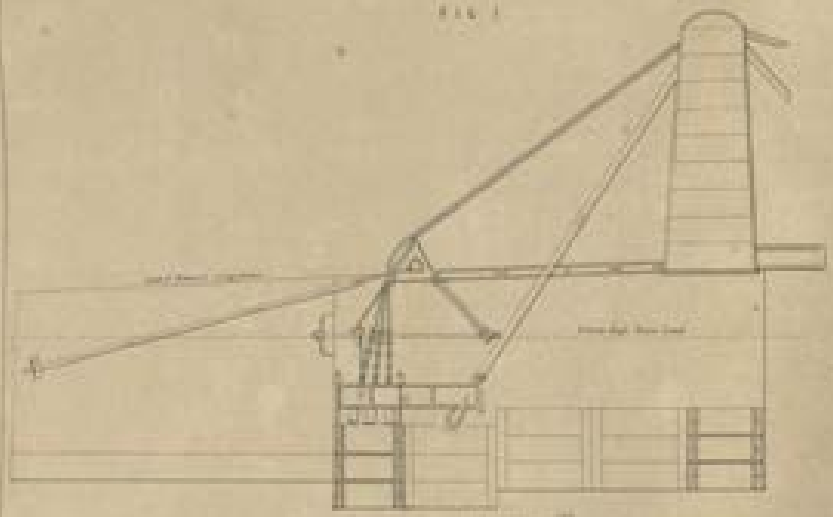


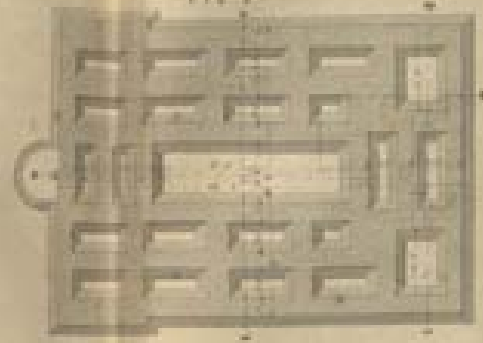


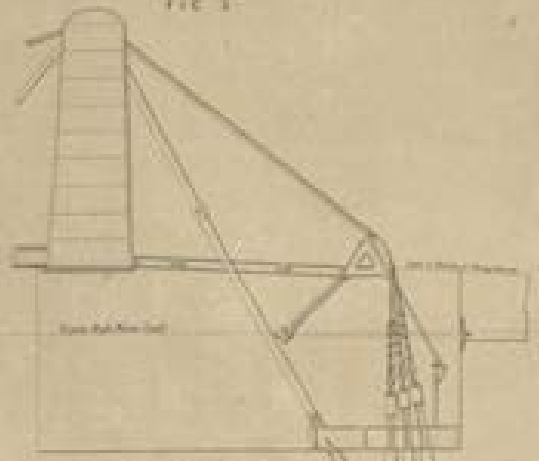
LAMBETH SUSPENSION BRIDGE.

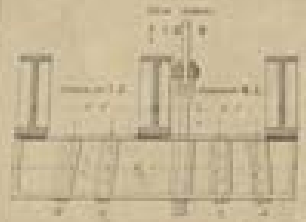
N°4.

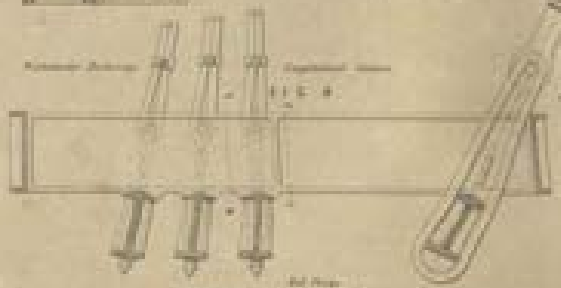
DETAILS OF ABUTMENT A°

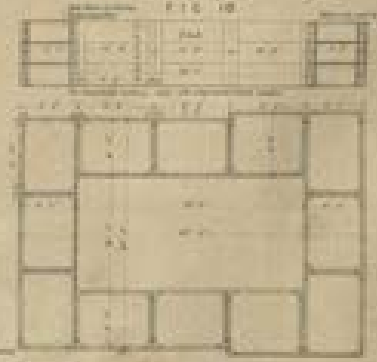


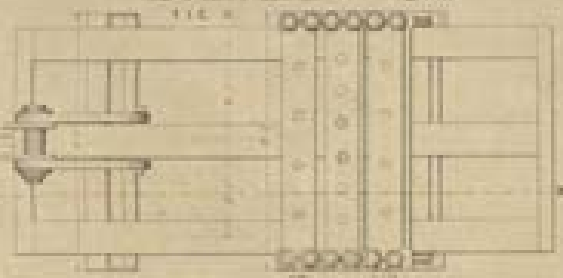


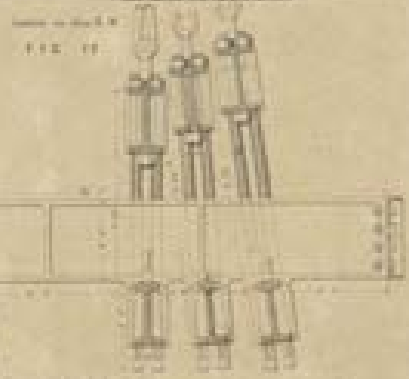


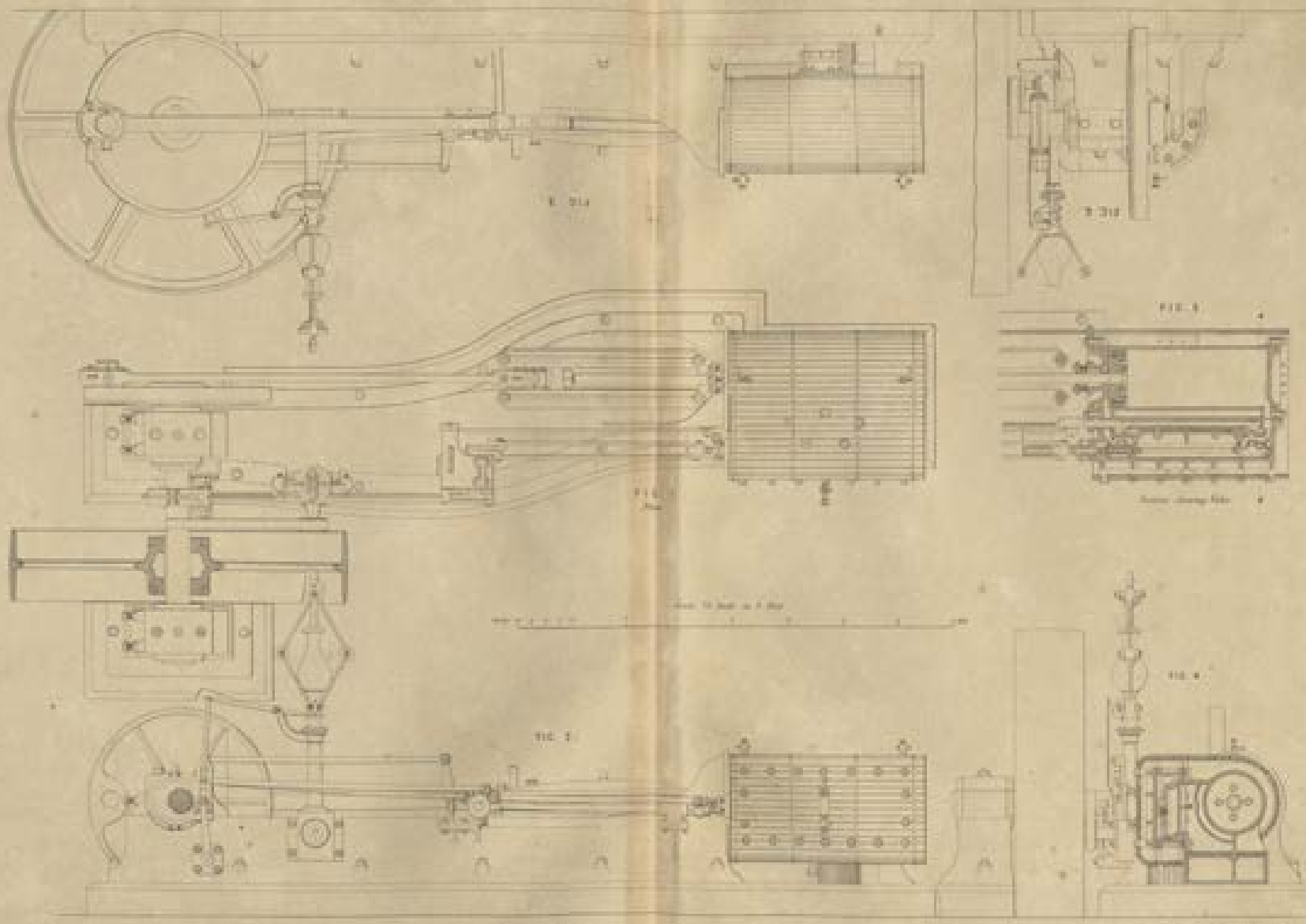








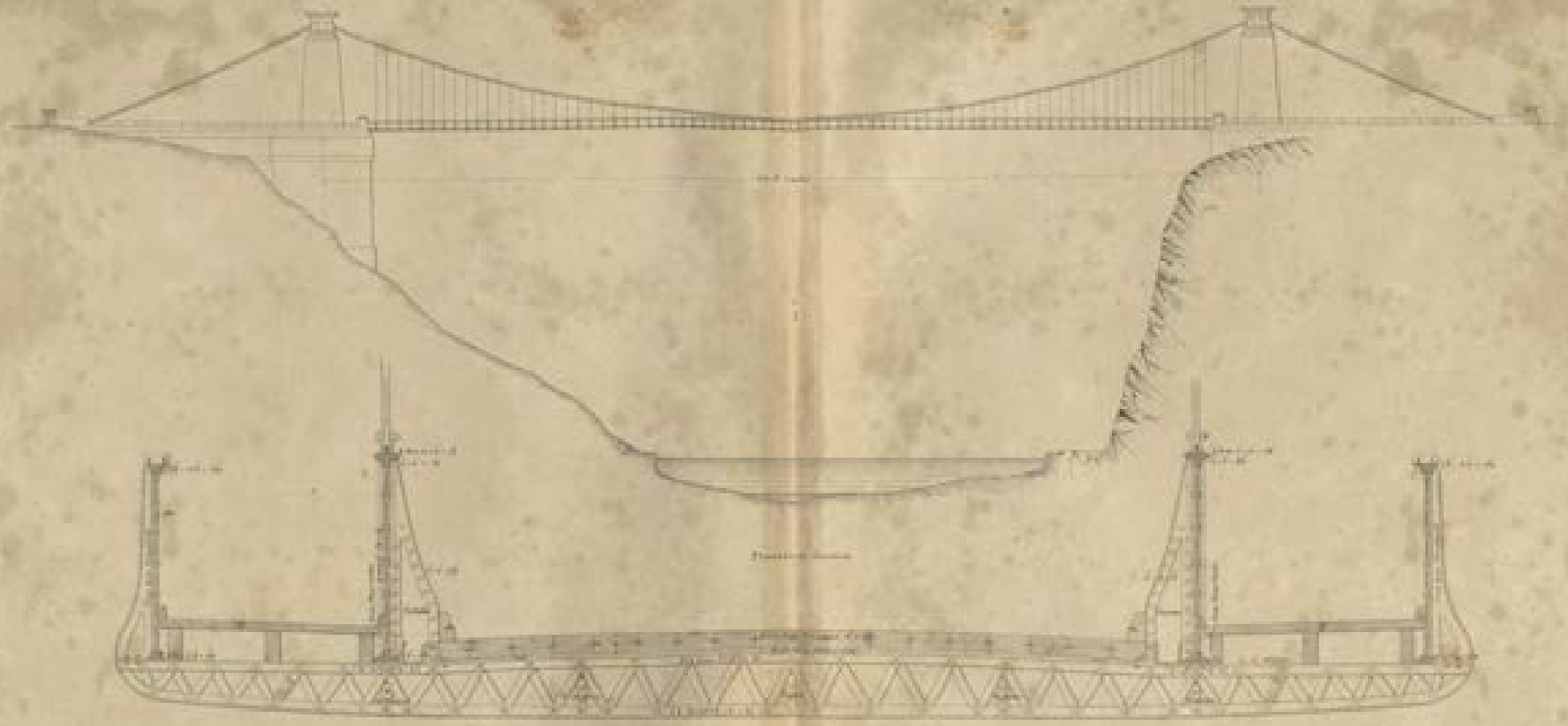




CLIFTON SUSPENSION BRIDGE.

No 1.

ELEVATION N.



CLIFTON SUSPENSION BRIDGE.
No 2.

FIG 1

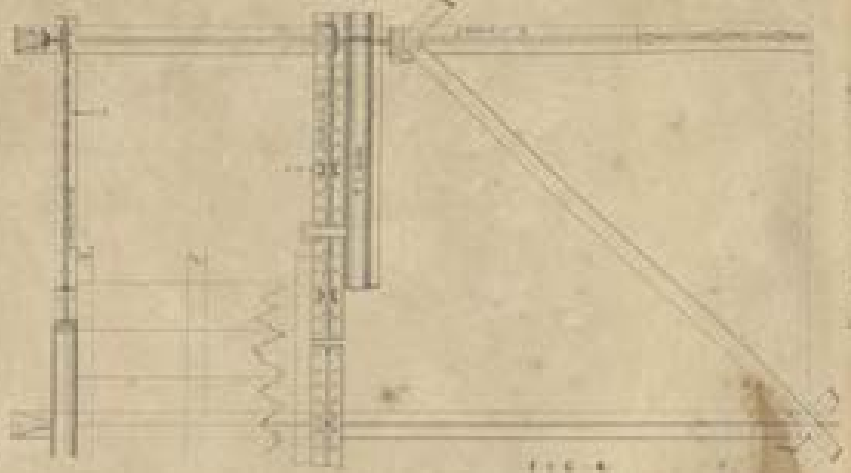


FIG 2

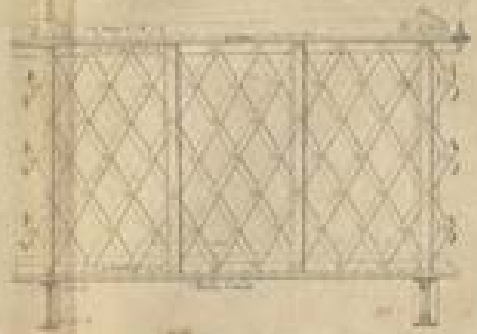


FIG 3

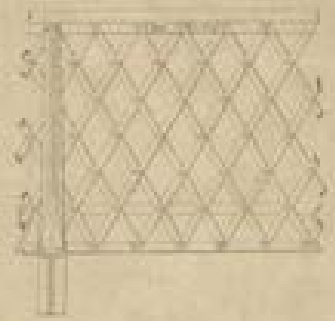


FIG 4

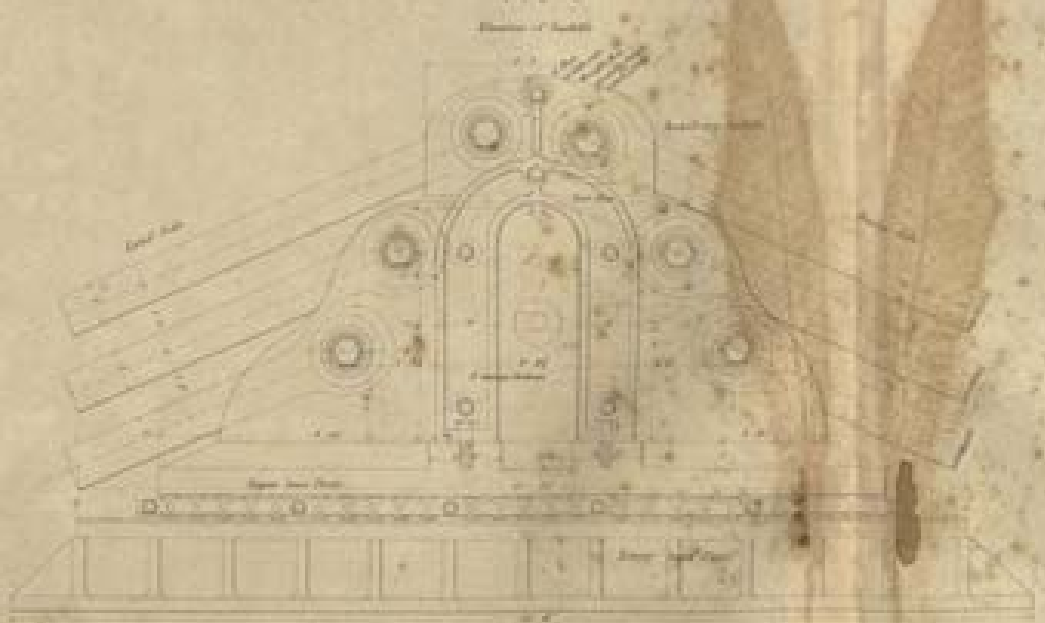
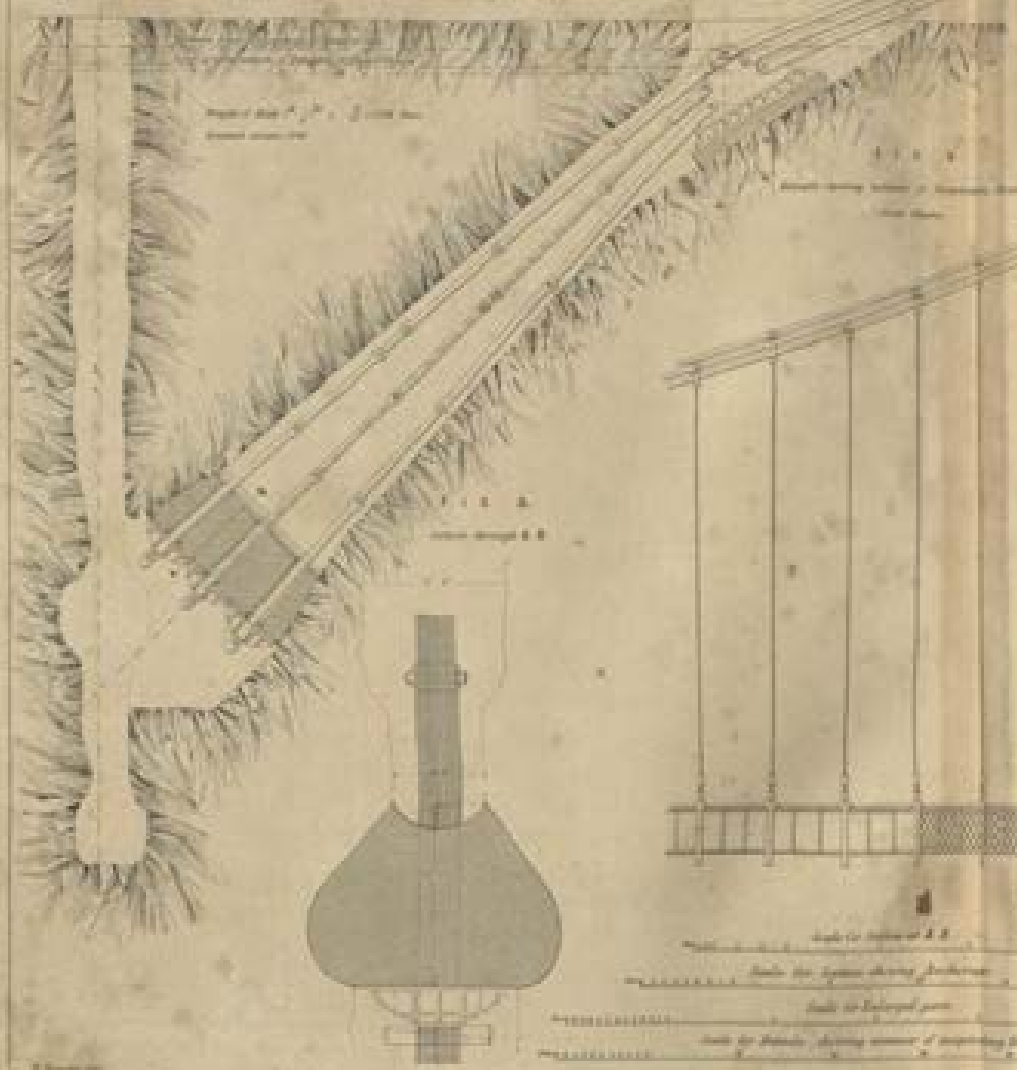
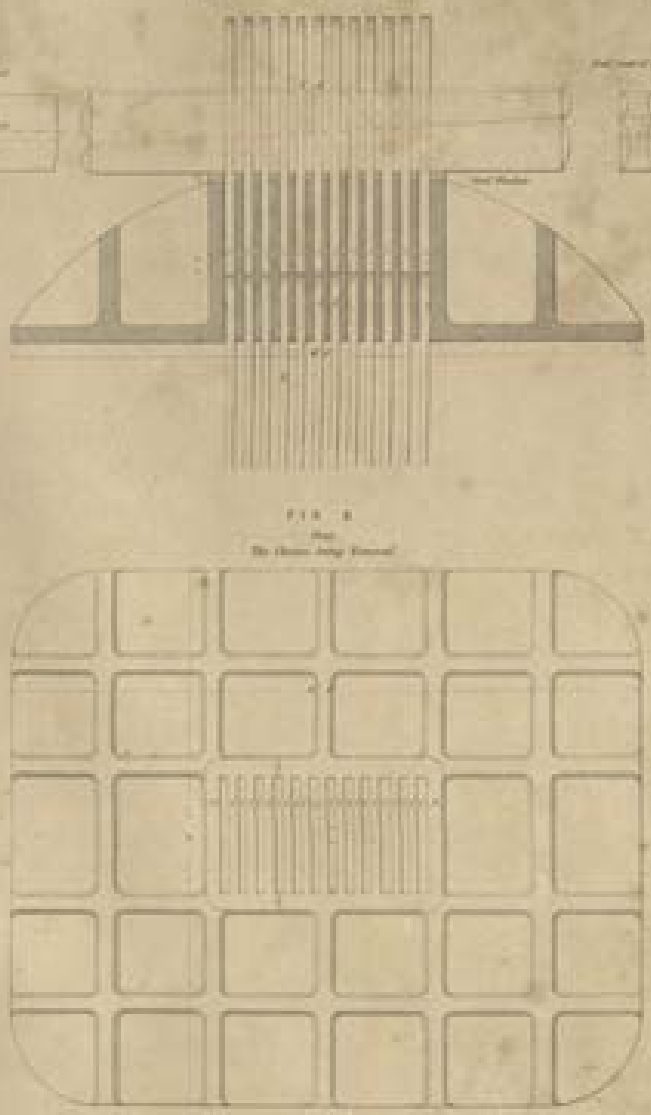


FIG 5

CLIFTON SUSPENSION BRIDGE





METROPOLITAN RAILWAY.

HOUSE STREET STATION, ETC.

Minutes of the Proceedings of Institution of Civil Engineers, Session 1862-63. PLATE 14.

FIG. 1.

DETAILS OF COVERED WAY.

Section under Street

FIG. 2.

DETAILS OF ARCHING — GREAT NORTHERN BRANCH.

FIG. 3.

DETAILS OF COVERED WAY.

FIG. 4.

FIG. 5.

FIG. 6.

FIG. 7.

FIG. 8.

FIG. 9.

FIG. 10.

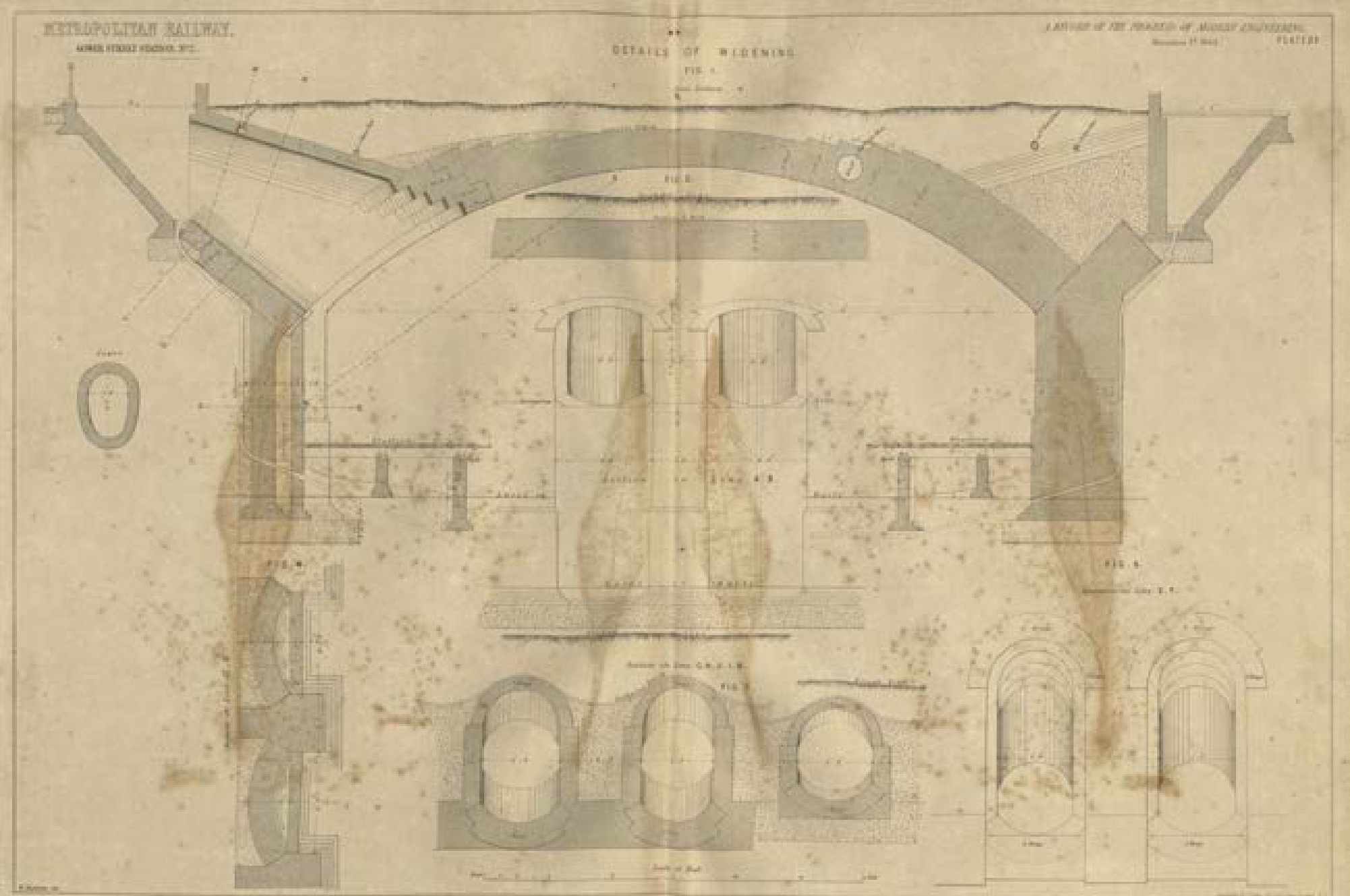
FIG. 11.

FIG. 12.

METROPOLITAN RAILWAY.

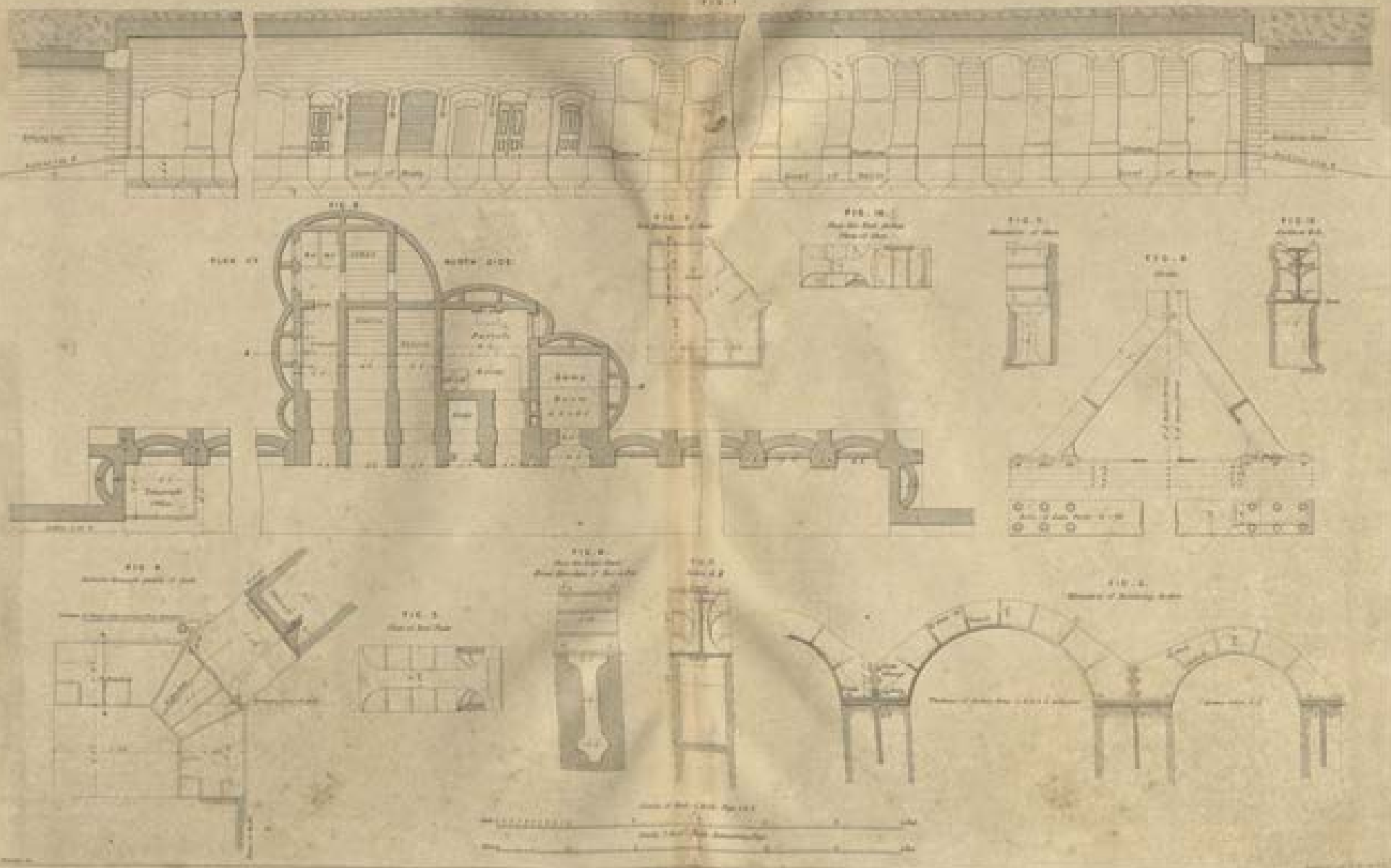
ALDWYCH STREET STATION, W.C.

DETAILS OF WIDENING.



METROPOLITAN RAILWAY.

TOWER STREET STATION. No 2.



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